OPERATING AND INSTRUCTION MANUAL

MODEL 301A
BROADBAND
PHASE ANGLE VOLTMETER

S-1125

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S-1125

This equipment is covered by Patents Nos. 3,267,358 and 3,267,359. Other patents are pending.

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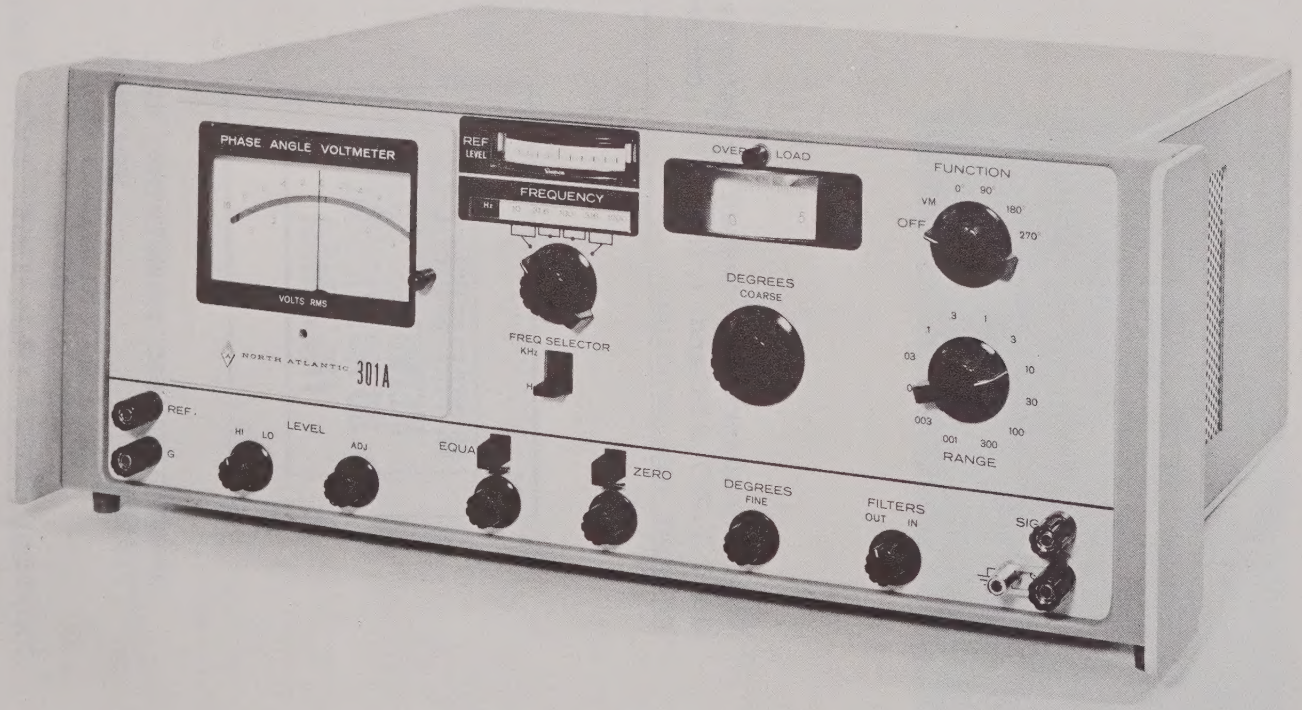
PHASE ANGLE VOLTMETER
VOLTS RMS
NORTH ATLANTIC 301A
REF LEVEL
FREQUENCY
Hz
FREQ SELECTOR
KHz
OVER LOAD
DEGREES
COARSE
FUNCTION
OFF
VM
0°
90°
180°
270°
.3
1
.1
3
03
10
30
003
100
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300
RANGE
REF.
G
HI
LO
LEVEL
ADJ
EQUA
ZERO
DEGREES
FINE
FILTERS
OUT
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TABLE OF CONTENTS

SECTION I - GENERAL DESCRIPTION	1.1
Introduction	1.1
Applications	1.2
Accessories	1.3
General Specifications	1.5
SECTION II - OPERATING INSTRUCTIONS	2.1
Removal from Package	2.1
Power Line Voltage and Cable	2.1
Controls, Displays, Inputs	2.2
Operation	2.8
To Measure Voltage	2.8
Precise Phase Angle Measurements - Preliminary Adjustments	2.9
Phase Angle Measurements - With Calibrated Phase Shifter	2.10
Phase Angle Measurements with In-Phase and Quadrature Components	2.11
Sweep Frequency Measurements	2.12
Filter Operation	2.13
General	2.13
Filter Adjustment	2.16
Table 2.1	2.14
Table 2.2	2.18
Table 2.3	2.20
SECTION III - THEORY OF OPERATION	3.1
Signal Channel	3.1
Input Attenuator and Preamplifier	3.1
Signal Amplifier	3.5
Reference Channel	3.7
Input Attenuator and Preamplifier	3.7
Reference Amplifier	3.7
Phase Networks	3.10
ZERO and EQUAL Control	3.10
Reference Drive Amplifier	3.14
Phase Sensitive Rectifier	3.14
Effects of Distortion	3.18
Power Supply	3.19
Frequency Switch (S6) Interconnections	3.22

(cont'd)

TABLE OF CONTENTS
(continued)

SECTION IV - MAINTENANCE	4.1
Cover Removal	4.1
Tube Replacement	4.2
Replacement of Parts	4.2
Reference Level Meter Replacement	4.4
Replacement Parts List	4.5
SECTION V - TEST AND ALIGNMENT PROCEDURE	5.1
Test Procedure	5.1
Test Equipment Required	5.1
Alignment Procedure	5.6
APPENDIX	
Application Notes	
Warranty	
Sales Offices	
Warranty Registration Cards	

LIST OF ILLUSTRATIONS

SECTION I		
Figure 1.1	Photograph	
SECTION II		
Figure 2.1	Power Transformer Primary Variations	2.3
Figure 2.2	90° Signal Amplitude Characteristics	2.13
Figure 2.3	Typical Filter Curve	2.17
Figure 2.4	Typical Filter Characteristics	2.19
SECTION III		
Figure 3.1	Functional Schematic	3.2
Figure 3.2	Signal Preamplifier	3.4
Figure 3.3	Signal Amplifier	3.5
Figure 3.4	Reference Preamplifier	3.8
Figure 3.5	Reference Amplifier	3.9
Figure 3.6	90° Signal Amplitude Characteristics	3.11
Figure 3.7	Monitor Voltmeter	3.13
Figure 3.8	Reference Driver Amplifier	3.15
Figure 3.9	Simplified Phase Sensitive Demodulator	3.16
Figure 3.10	Power Supply	3.20
Figure 3.11	Frequency Switch (S6) Wafer "A"	3.21
Figure 3.12	Frequency Switch, Board #1	3.23
Figure 3.13	Frequency Switch, Board #2	3.24
Figure 3.14	Frequency Switch, Board #3	3.25
Figure 3.15	Associated Circuits External to Frequency Switch	3.26
Figure 3.16	Phase Shift Networks	3.27
SECTION IV		
Figure 4.1	Signal Preamplifier Board Assembly	4.6
Figure 4.2	Signal Amplifier Board Assembly	4.12
Figure 4.3	Reference Preamplifier Assembly	4.16
Figure 4.4	Reference Amplifier Assembly	4.20
Figure 4.5	Frequency Switch, Deck #1, Rear	4.23
Figure 4.6	Frequency Switch, Deck #1, Front	4.24
Figure 4.7	Frequency Switch, Deck #2, Front	4.26
Figure 4.8	Frequency Switch, Deck #2, Rear	4.27
Figure 4.9	Frequency Switch, Deck #3, Front	4.30
Figure 4.10	Frequency Switch, Deck #3, Rear	4.31
Figure 4.11	Terminal Board Assembly, TB6	4.34
Figure 4.12	Terminal Board Assembly, TB6A	4.35
Figure 4.13	Monitor Voltmeter Terminal Board Assembly	4.38

(...cont'd)

LIST OF ILLUSTRATIONS
(Continued)

SECTION IV (cont'd)		
Figure 4.14	Reference Drive Amplifier Assembly	4.43
Figure 4.15	Power Supply Terminal Board Assembly	4.49
Figure 4.16	Meterboard Assembly	4.51
Figure 4.17	Signal Decoupling Board Assembly	4.53
Figure 4.18	Signal Filter and Overload Assembly	4.55
Figure 4.19		4.63
SECTION V		
Figure 5.1	Top View	5.32
Figure 5.2	Bottom View	5.33
Figure 5.3	Test Connections	5.34

CAUTION

High voltage exists at several points in the instrument. Normal precautions consistent with good practice should be taken to reduce shock hazard.

A potential shock hazard exists when ungrounded power source or ungrounded case operation is employed. Persons operating the instrument should be made aware of and take precautions against this condition.

North Atlantic Industries, Inc. cannot be held responsible for damage to person or property in the process of or as a result of maintenance, calibration, or setting up of the instrument.

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SECTION I

GENERAL DESCRIPTION

INTRODUCTION

The Model 301A Broadband Phase Angle Voltmeter, shown in the photograph of Figure 1.1, combines in one instrument the ability to measure both phase angle and magnitude of complex AC signals and their vector components with respect to a reference voltage. Designed to operate over the frequency range from 10Hz to 100KHz, it utilizes passive phase shifter circuits (patents applied for) to assure high accuracy over this spectrum. Because of these broadband characteristics, the Model 301A fills a long existing need for a null and phase meter in which the signal frequency may vary. Measurements of AC ratios, phase angles, and related quantities may be made with non-stable frequency sources, or while sweeping frequency to determine phase vs. frequency characteristics.

Front panel controls permit instantaneous selection of range, function and frequency band. As a phase sensitive null meter, the instrument's 2 microvolt sensitivity permits high resolution ratiometric measurements. This requires measurement of low-level voltages of the reference frequency in the presence of noise, hum and other spurious signals. As a phase meter, angles are read on a high resolution, parallax-free scale, calibrated in 0.2^{o} increments. Two simple push and set controls permit trimming to the existing source frequency to achieve best absolute accuracy. Plug-in, interchangeable harmonic filters are available and can be simply installed or removed from the front of the instrument without disassembly.

High input impedance signal and reference channels minimize errors due to loading and common ground signals. Reference levels may be anywhere in the range of 150mV to 150V. Successful measurements can be made with reference levels less than half of the lower value or 75mV.

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APPLICATIONS

A. Phase sensitive null indicator.

B. Measure separately the in-phase and quadrature components of an AC signal.

C. Measure phase shift in any AC system.

D. Sensitive AC voltmeter.

E. Testing of servos, computers, synchros, resolvers, inductosyns.

F. Precise AC ratiometry.

G. Phasing of servo motors, chopper amplifiers, magnetic amplifiers.

H. Measuring both torque and non-torque producing signals in servo amplifiers.

I. Align carrier amplifier and notch networks.

J. Impedance meter.

K. Power factor meter.

L. Measuring response of vibrational system.

Detailed descriptions of these applications are shown in the Application Notes appended hereto.

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ACCESSORIES

Filters

Filters of the low pass plug-in type can be supplied in the range of 28Hz to 28KHz for harmonic rejection in both signal and reference channels. Special band pass filters are available for these and higher frequencies, if necessary. These filters may be plugged into the unit and switched in and out of the circuit from the front with no disassembly.

P-201 Reference Isolation Module

This plug-in module is intended for applications which require that the external reference signal generator be isolated from the reference and signal channels of the measuring instrument. It will eliminate errors due to extraneous currents in the signal circuits from common ground connections. The module plugs directly into the banana jacks of the reference input on the Model 301A Broadband Phase Angle Voltmeter.

P-203 Universal Isolation Module

This module is a plug-in transformer module designed for precision bridging and signal or reference isolation application in phase sensitive AC voltage measurements and AC ratiometry. The unique shielding design incorporates special separate shielding of the primary and secondary windings. It can be used as a precision bridging transformer for establishing null voltages in critical AC measurements. Used as a signal isolation transformer, it allows the signal source to be isolated from the measurement instrument and power ground without detriment to the measurement accuracy. This design provides absolute minimum coupling of the primary common mode signal into the secondary winding.

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Other isolation transformers are available for special applications. Information regarding these transformers and their applications may be obtained by contacting North Atlantic Industries, Inc.

NOTE: THE PROPER APPLICATION OF THESE MODULES EXTENDS THE VERSATILITY OF AC PHASE DETECTION AND RATIOMETRIC INSTRUMENTS TO A WIDE RANGE OF MEASUREMENT TASKS IN ACTUAL SYSTEMS WHERE GROUND LOOPS AND EXACT MEASUREMENT CONDITIONS CANNOT BE DEFINED OR PREDICTED IN ADVANCE. THESE PRECISION MODULES ARE DESIGNED TO BE UNIVERSALLY USED WITH ANY AC RATIOMETRIC AND PHASE DETECTION INSTRUMENTS PROVIDED WITH STANDARD 3/4" SPACED BANANA JACKS, SUBJECT TO FREQUENCY RESPONSE.

Front Panel Dress Kit

This kit is available for bench mounting of the instrument. It consists of a front panel trim piece and handles which attach to the ends of the front panel. These handles also contain extendable legs for raising the front of the instrument to improve reading and operating ease.

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GENERAL SPECIFICATION

The following specification applies to all North Atlantic Model 301A Broadband Phase Angle Voltmeters. Where a special modification or variation is involved, the governing specification will either be a separate specification control document, the buyer's purchase order, or a supplement contained in this manual. Specifications for special instruments are identified by the specification "S" number appearing on the instrument nameplate, e.g., Model 301A-S1234.

Electrical

Voltage Range:	Full scale 1mv to 300V in 12 ranges.
Frequency Range:	FILTERS OUT: VM: 10Hz to 100KHz 0°,90°,180°,270°: 10Hz to 100KHz (selected in half-decade frequency steps by front panel controls). FILTERS IN: VM, 0°,90°,180°, and 270°: Any frequency within band of 28Hz to 28KHz determined by plug-in filters (other frequencies available on special request).
Voltage Accuracy:	±2% full scale over full frequency range.
Calibration:	Meter: Zero center mirror scale, 3-0-3 and 10-0-10 scales. Phase Angle: 0° - 90° calibrated degrees phase dial with 0.2° magnified divisions. Dial has 2° overlap into adjacent quadrants, selector covers 0-360° non-ambiguously.

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Phase Accuracy:	Using Zeroing Procedure found on page 2.10: 1. ± 0.25° from 31.6Hz to 31.6KHz. 2. 31.6KHz to 100KHz: Gradual degration to ±1° at 100KHz as frequency is increased. 3. 10KHz to 31.6Hz: Gradual degradation to ±0.6° as frequency is decreased.
Max. Zero Switch Angular Offset:	1. 0.1° from 31.6Hz to 10KHz. 2. 0.2°from 10KHz to 100KHz. 3. 0.2° from 10Hz to 31.6Hz.
Sweep Frequency Capability:	(See Text, Section II, "Sweep Frequency Measurement", for discussion). Degrees phase dial at cardinal angles: 2° nominal from 10Hz to 31.6Hz. 7° nominal from 31.6HKz to 100KHz. (Zero and Equal controls set arbitrarily). Degrees phase dial at 45°, 2.5° nominal. (Equal control set at approximately 84% or 26% top frequency in half decade).
Phase Resolution:	0.03° at 10 x overload (1/4 Div.)
Input Impedance:	Signal: 10 megohms, 47μμf, nominal, all ranges. Reference: 10 megohms, 47μμf, nominal, Both high and low ranges.
Reference Level:	Variable from 0.15V to 150V by HI-LO selector plus vernier adjust.
Input DC Voltage Level:	DC levels may be applied without affecting performance such that the peak value of the combined AC and DC voltages shall not exceed 600V in the signal input and 1000V in the reference input.

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Overload:	OVERLOAD lamp lights at input 11 x full scale setting.
Noise (VTVM):	FILTER OUT: Less than 20 microvolts FILTER IN: Less than 30 microvolts
Nulling Sensitivity (Phase Sensitive):	Less than 2 microvolts in phase sensitive modes (0°, 90°, 180°, 270°).
Harmonic Rejection:	Low pass sharp cut off plug-in filters (28Hz to 28KHz range) rejection of 30DB outside pass band. By proper choice of filter, this may be increased to 50DB for any specific frequency. In addition, detector characteristics reject all even-order harmonics by greater than 55DB as well as odd-order harmonics in inverse proportion to the harmonic order. ie 10DB for 3rd harmonic, 14DB for 5th harmonic, etc.)
Non-Coherent Signal Rejection:	For frequencies removed from signal frequency by approximately 5Hz or more (effective pass band of meter movement) response is essentially nil for levels up to 10 times the value of the full scale in use. Appropriate filters can increase the allowable level of the non-coherent signal to 300 times the value of the full scale in use on the most sensitive scales.
Power:	115/125 or 230/250 volts ± 10%, 50Hz to 60Hz*, 80 watts. Fused @ 2 amp. for 115/125V operation, 1 amp. for 230/250V operation (3AG Slo-Blo or equal). *(400Hz power available on special order)

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Mechanical

Size:	Panel: 7" x 19" x 1/8" with standard RTMA rack mount slots. Depth Behind Panel: 13-1/2"
Weight:	32 lbs. approximate.
Mounting:	Unit can be optionally supplied with front panel decorative bezel and handles with recessible feet, for bench use. These can be removed for rack mounted applications.
Front Panel Paint:	Gray #26440 Fed. Std. 595.
Front Panel Marking:	Black #27038 per Fed. Std. 595.
Power Cord:	6' long minimum.
Front Panel:	Inputs are standard five-way binding posts spaced on 3/4" centers. Ground terminals are colored Black and marked "GND." High side of inputs are Red Terminals. Chrome terminal represents chassis ground.

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SECTION II

OPERATING INSTRUCTIONS

REMOVAL FROM PACKAGE

This instrument has been thoroughly tested, inspected, and evaluated at the factory prior to shipment. Particular care has been taken in the design of the special wrapping and packaging material used in the container to ensure that no damage results from the typical handling encountered during shipment. However, upon removal from package, the instrument should be externally inspected for any obvious damage. Should such be observed, refer to Warranty in the rear of this instruction manual.

Prior to making any connection, check meter to see that it reads zero. If it does not, reset the meter to read zero by means of the adjusting screw in the meter door just under the meter face. This adjustment must be done with the power off and with the instrument in a horizontal or near horizontal position.

POWER LINE VOLTAGE AND CABLE

The Model 301A is equipped with a power transformer which has a split primary. All units may be connected to operate from either 115V or 230V at 50 - 60Hz. Some instruments contain additional taps which permit operation from higher line voltages (i.e. 125V or 250V, see Power Supply Schematic, Figure 3.9, for alternate primary configurations).

All Model 301A instruments are wired for 115 volts at the factory. The conversion to any of the other configurations may be accomplished in the following manner (see Figure 2.1):

1. Remove jumpers, Pins 4 to 11 and 15 to 16
2. For 125V, connect Pins 11 to 23, and 18 to 24
3. For 230V, connect Pins 4 to 16.

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4. For 250V, connect Pin 23 to 24.

All connections between the power input leads and the power transformer primary windings are made to individual terminals on TB4. The above changes and the change of Fuse F1 from 2 amp. to 1 amp. are all that are necessary to make this conversion. TB4 is located below the power transformer on the rear sub-panel.

CAUTION: USE THE PROPER FUSE FOR EACH VOLTAGE.
(3AG, Slow-Blow)

115V/125V Source - 2 Amp Fuse
230V/250V Source - 1 Amp Fuse

All electrical circuit and power grounds are floating with respect to chassis. The instrument is supplied with a three prong power plug, the round pin is wired to the chassis. Common grounding of power, chassis, and circuit ground is accomplished by means of a link on the signal input terminals. The circuit ground must be connected to chassis ground either at the input terminals or remotely. Dependent upon specific applications, it may be more desirable to wire the chassis such that it is not connected directly to house ground.

In those cases, extreme caution must be taken to avoid any personal injuries due to the resultant shock hazard. As a general rule, every effort must be made to ensure that the chassis is wired to a house ground at all times.

CONTROLS, DISPLAYS, INPUTS

Prior to attempting to operate this instrument, it is advisable that the user familiarize himself with every control, display and input connection as described below.

POWER TRANSFORMER PRIMARY
VARIATIONS - 115V, 125V, 230V, 250V

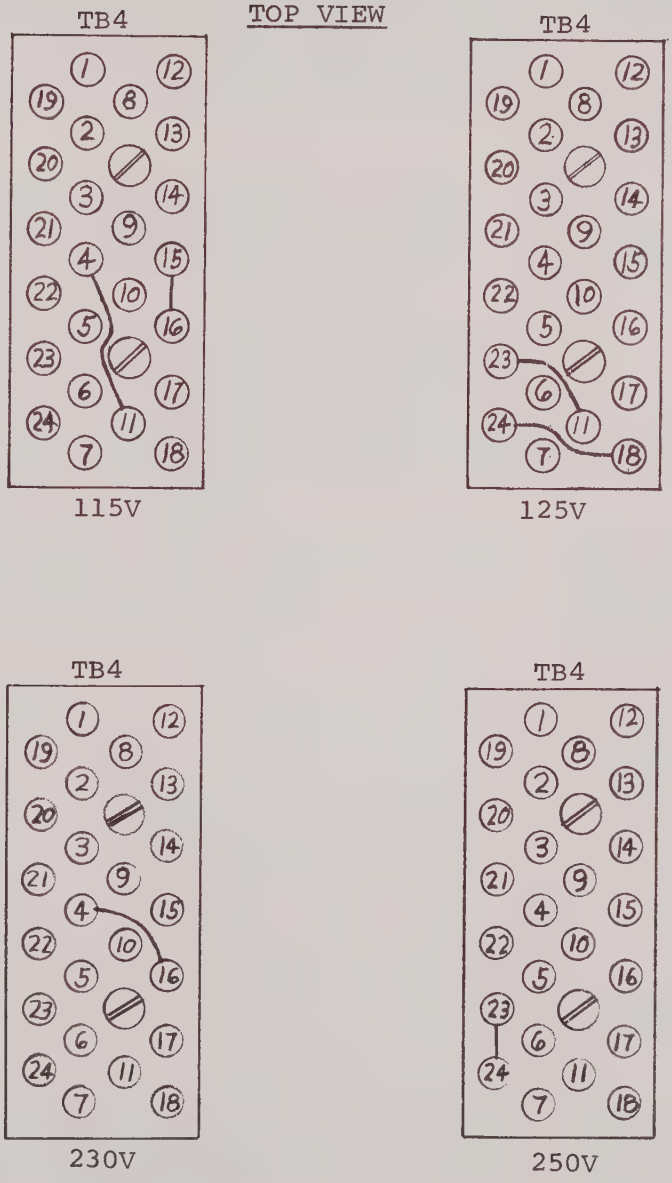

Figure 2.1

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RANGE Switch

A rotary switch which selects the proper multipliers for the desired voltage range. The RANGE Switch indicates the full scale voltage at each position.

FUNCTION Selector

The FUNCTION Selector contains the on/OFF Switch which turns the instrument on when rotated to any desired mode of operation. In the four phase-sensitive positions, the instrument is connected so that it may read a voltage E cos α where α is defined as the angle by which the signal vector leads the reference vector. The FUNCTION Selector selects the quadrant over which the calibrated phase shifter will operate. Thus, the total angle shifted in degrees will be either 0^{o}, 90^{o}, 180^{o}, or 270^{o}, plus the reading of the Phase Dial.

In the VM position, the instrument functions as a standard voltmeter. With the Filter Switch in the FILTER IN position, the instrument will read the total vector voltage of the fundamental signal.

FREQUENCY Selector

This dual switch selects the desired frequency range in half-decade steps. The entire frequency band is divided into two spectrums, 10Hz to 1KHz and from 1KHz to 100KHz. The slide switch selects either the high or low spectrum. The small pointer knob then selects the proper half-decade step within the spectrum. The spectrum and half-decade steps are indicated on the flag which changes position when the HZ/KHZ slide is switched.

FILTER Selector

This inserts the harmonic attenuation filters either into or out of the Signal and Reference Channels simultaneously.

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Reference LEVEL Switch and Control

This LEVEL HI-LO switch and the associated LEVEL ADJust potentiometer, allows a wide range of reference (.15V to 150V) to be used. This is not a calibrated control and for proper adjustment of the Reference HI-LO and LEVEL Control, see the REFerence LEVEL Meter description in this section.

NOTE: These controls should be set to maintain an on-scale reading of the REFerence LEVEL Meter at all times.

ZERO Switch, EQUAL Switch, and Controls

Combined, these controls perform the necessary trimming of the two Amplifier Channels and Phase Shifter Networks to align the instrument for the most accurate phase measurements at a specific frequency.

Filter Amplitude Adjustment

This control is mounted on the right side of the meter door and is available when the door is open. It is used when changing filters to compensate for the difference in insertion loss associated with the filters. Information regarding its use is presented in the section describing filter operation.

Voltmeter

The meter is a zero center DC milliammeter calibrated to read the RMS value of a sine wave. For VM readings, the needle deflects to the right. For phase-sensitive readings, the meter deflection may be to the left or right. (See Phase Angle Measurement with Calibrated Phase Shifter, this section, for meaning of deflection right or left.) It has calibrated zero center 3-0-3 and 10-0-10 scales.

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CAUTION: BY ITS NATURE, THE INSTRUMENT IS REQUIRED TO HANDLE INPUTS CONSIDERABLY IN EXCESS OF ITS FULL SCALE READING. DAMAGE MAY OCCUR IF THE SIGNALS ARE APPLIED IN A MANNER WHICH WILL DRIVE THE NEEDLE HARD AGAINST THE STOPS. THEREFORE, ALWAYS APPROACH A MEASUREMENT FROM THE LEAST SENSITIVE POSITION AND RETURN TO THIS POSITION BEFORE MAKING CIRCUIT ADJUSTMENTS.

REFerence LEVEL Meter

This zero suppressed meter indicates the reference voltage level within the phase shift networks. This is used for phase reference level adjustments and phase network trimming purposes. Its use is described in the section dealing with REFerence LEVEL adjustment. (Note: Set Reference LEVEL Controls to maintain an on-scale reading at all times.)

DEGREES Phase Dial

A dial is calibrated to read the degrees of phase shift introduced by the calibrated phase shifter network within the particular quadrant selected by the FUNCTION Selector. The dial is calibrated -2^{o} to $+92^{o}$ in 0.2^{o} graduations. Mechanical positioning of the dial on its shaft is critical and for this reason should it be necessary to repair or replace, the procedure under "Phase Dial Alignment" should be followed.

OVERLOAD Indicator

The lamp marked OVERLOAD lights whenever a prescribed signal level is exceeded. As the signal reaches the overload condition, the lamp will blink. A steady glow indicates a large overload condition. This indication warns of impending amplifier overload and the attendant inaccuracies which will occur when large saturating signals are present. The overload indicator is factory set to blink at eleven (11) times full scale.

Input Terminals

Five terminals are provided at the front panel for connection to external test circuits. Terminals for both the SIGnal and REFerence inputs are colored Black for circuit ground and colored Red for the high side of the input. These posts which are on a standard 3/4" spacing will accommodate banana plugs, wire, or alligator clips.

CAUTION: MAXIMUM SIGNAL INPUT MUST NOT EXCEED 600 VOLTS AND MAXIMUM INPUT REFERENCE MUST NOT EXCEED 1000 VOLTS (COMBINED PEAK AC & DC LEVELS). HIGHER VOLTAGES WILL BREAK DOWN THE INPUT CAPACITORS IN THE INSTRUMENT.

A third terminal is provided on the signal input for connecting circuit ground to chassis ground. As the voltmeter circuit grounds are floated above chassis, a link is provided between the metal terminal and the ground (Black) terminal of the signal input to allow maximum flexibility of connections. Great care should be given to grounding methods used to avoid ground loops and stray fields. The instrument will not read properly if the input is ungrounded or improperly grounded. The link is provided to permit grounding to a remote point in a measuring set up.

Filters

Harmonic attenuation filters can be supplied in single frequency pairs for a specified band of frequencies in the range from 28Hz to 28KHz. These are plug-in units located behind the meter and accessible by opening the meter door. More information is presented later under Filter Operation .

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Fuses

The fuseholder mounted on the back of the instrument will accept either a 2 amp Slow-Blow or 1 amp Slow-Blow, 3AG type, depending upon the line voltage as previously described. (See Page 2.2)

OPERATION

Plug the instrument into the proper power source and turn the FUNCTION Selector to any mode. Allow the instrument to warm up about 15 minutes for stable operation. For the most precise phase measurements, additional time should be allowed.

CAUTION: BEFORE MAKING PHASE OR VOLTAGE MEASUREMENTS, REVIEW THE SECTION ON GROUNDING TECHNIQUES IN THE APPLICATION NOTES.

To Measure Voltage

Set the RANGE Switch to the appropriate scale and the FUNCTION Selector to the VM position. Connect the voltage to be measured to the SIGnal input terminals. Read the voltage from either the 0-10 volts or 0-3 volts using the proper scale factor as determined by the RANGE Selector position.

With the FUNCTION Selector in the VM position and the FILTER Switch in the OUT position, the voltmeter operates as a standard AC VTVM. This AC Voltmeter reads the total vector voltage at any frequency including all harmonic effects. With the FILTER Switch in the IN position and with the proper filters plugged into the instrument, the voltmeter will read only the fundamental voltage within the range of the filter.

Notice that with no input to the instrument, the meter needle deflects on the low ranges. This condition is normal and represents a true measurement of the stray fields capacitively coupled to the input. Shielding the input will reduce this deflection to effectively zero.

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With the instrument in the VM position, the REFerence LEVEL Meter to read off scale to the left. This is normal as the reference is disconnected internally in the VM position.

Measurements made on high impedance circuits require that special attention be paid to capacitive as well as inductive pickup. Twisted and/or shielded cable will reduce the effect although the cable capacity could serve to load the source.

Care must also be taken to ensure that error producing ground loops do not exist by virtue of the signal and reference grounds or "low" being connected internally as well as to the instrument case.

Precise Phase Angle Measurements - Preliminary Adjustments

1. Set the FREQUENCY Selector to the proper band for the frequency to be measured.

2. Switch FUNCTION Selector to a phase-sensitive position, eg 0°.

3. Connect the reference voltage to the REFerence input terminals of the instrument. With the Reference LEVEL HI-LO Switch and REFerence LEVEL Control, adjust the reference input to give an on scale reading on the REFerence LEVEL Meter. (No particular setting is required, as the instrument will operate over a wide range of reference level. As long as an on scale reading is maintained, the instrument will remain within calibration tolerances.

4. Depress the EQUAL Switch and note if there is any change in REFerence LEVEL Meter from that observed in Step 3.

5. With the EQUAL Adjust Knob, readjust the REFerence LEVEL meter to original reading. Adjust this control until there is no change in this meter reading when the EQUAL Switch is depressed or released.

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6. Internal Zero Adjustment

Depress the Zero Switch and using the ZERO Adjustment Knob, adjust the instrument to read exactly zero. Release the ZERO Switch and proceed with the measurements.

External Zero Adjustment

The most precision phase measurements may be made when the signal channel and reference channel are phase aligned as closely as possible, with respect to the input terminals. This may be accomplished in the following manner:

NOTE: If the VM301A is to be used at a single frequency, the above procedure may be followed for the initial zeroing. The ZERO switch may then be depressed and the offset noted. This offset is stable and may be adjusted out with the ZERO control (with the ZERO switch depressed). All further measurements may be made using the ZERO switch.

1. Perform step 1 thru 5 on page 2.9.

2.. Connect a portion of the reference voltage to the SIGnal input terminals.

NOTE: If the signal to be tested is 3V or less, the voltage used here should be set to 3V. If the signal to be tested is greater than 3V, the voltage used here should be greater than 3V. In both cases this voltage should be set close to a full scale value.

3. Set the FUNCTION selector to VM position.

4. Set the RANGE switch to the macimum on scale reading.

5. Set the DEGREES Phase Dial to precisely 0°, FUNCTION switch to 90°.

6. Set the RANGE switch down two positions. (Higher sensitivity: i.e. with 10V signal, set RANGE Switch to 1V).

7. Adjust the ZERO control to cause an exact null (do not depress ZERO Switch).

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NOTE: The above steps have aligned the Model 301A Broadband Phase Angle Voltmeter for accurate measurements at a particular frequency. Maximum accuracy may be had at any frequency within the spectrum of 10Hz to 100KHz by following this procedure. The EQUAL procedure outlined in Steps 4 and 5 need only be done if the DEGREES Phase Dial is to be used at other than 0° or 90°. (see Theory of Operation)

Phase Angle Measurements - With Calibrated DEGREES Phase Dial

1. Adjust the Reference Channel as described in Step 3 above.

2. Set the FUNCTION Selector to VM position.

3. Set the RANGE Switch for maximum on-scale reading.

4. Set DEGREES Phase Dial to 0° and FUNCTION selector to 0°.

5. Set the RANGE Switch down to the next lower range position.

6. Turn the DEGREES Phase Dial for zero meter reading (null).

   NOTE: If a zero reading cannot be obtained in this manner, proceed with Step 7.

7. Switch FUNCTION Selector to 90° and adjust DEGREES Phase Dial for zero meter reading.

8. Switch FUNCTION Selector to the position which results in a positive up-scale reading. This may occur in any of the four phase-sensitive FUNCTION Positions and serves as a means of Quadrant Identification.

9. The Phase Angle is the sum of the FUNCTION Selector setting of Step 8 and the DEGREES Phase Dial reading.

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Phase Angle Measurements with In-Phase and Quadrature Components

Accurate measurement of phase angle can also be made using the E cos θ or E sin θ characteristics. Voltage measurements are made of the in-phase (0°) or quadrature (90°) component and of the fundamental signal (VM position with FILTER IN). The quotient will then be the cosine, or sine, or tangent of the unknown phase angle. Trigonometric tables, slide rule, or graphs included in the appended Application Notes are suitable for converting to degrees. The accuracy achievable using this technique depends upon the procedure, and for that reason, it is suggested the Application Notes be reviewed before using this method.

1. With Reference Channel adjusted as described in "Phase Angle Measurements - Preliminary Adjustment", place FUNCTION Selector in 0° position. Set the DEGREES Phase Dial at 0°.

2. The meter now reads the in-phase component of the signal. This is also E cosine α where α is the angle between the reference and signal.

3. Switch the FUNCTION Selector to 90°. The meter now reads the quadrature component of the signal which is E sine α. In general, one of these components is usually much smaller than the other and for greater accuracy, it is convenient to change the range of the instrument. This can be done until the OVERLOAD lamp blinks thereby warning of an impending overload condition. This light indicates that the total exceeds 11 times the full scale value.

4. Switch the FUNCTION Selector to the VM position. The meter now reads the fundamental component of the signal which is the vectorial combination of the measurements of 2 and 3.

5. Phase Angle can now be determined by using the quotient of any two of the measurements of 2, 3, and 4 and the appropriate trigonometric tables.

$$\alpha = \text{Sin}^{-1}\ \frac{E \sin \theta}{E \text{ Fund}}$$

$$= \text{Cos}^{-1}\ \frac{E \cos \theta}{E \text{ Fund}}$$

$$= \text{Tan}^{-1}\ \frac{E \sin \theta}{E \cos \theta}$$

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Sweep Frequency Measurements

If it is desired to make less accurate phase measurements while sweeping frequencies, it is possible to accomplish this without adjustment of the EQUAL or ZERO controls. To do this, it is necessary to understand the two sources of error inherent in this procedure.

The first is the phase misalignment between the Reference and Signal Channels that occurs as the frequency is varied. This is generally small within each half decade but can increase to a few degrees as the frequency is varied from decade to decade. This error will affect accuracy at all angles of the DEGREES Phase Dial. If it is desired to minimize this error, an adjustment of the ZERO control in the middle of each half decade band can be made.

The second source of error is due to the difference in the amplitude gradients of the internally generated 90^{o} and 0^{o} signals applied to the phase bridge. (See Theory of Operation.) The 0^{o} signal is relatively constant with frequency, but the 90^{o} signal varies in an identical parabolic manner from half decade to half decade. This voltage is a maximum at the two extremes of the half decade, dipping in the middle of the band to a value 18% below the value at the extremes. This pattern is repeated in every half decade. This parabolic curve is shown in Figure 2.2 for the 1KHZ - 3.16KHZ band. The function of the EQUAL control is to adjust the 0^{o} and 90^{o} voltage to equal amplitude. The error due to these two voltages not being equal is maximum at 45^{o} of the DEGREES Phase Dial (0.28^{o}/% of difference in amplitude) and has no effect at the 0^{o} or 90^{o} position of the DEGREES Phase Dial. Since this pattern is repeated from half decade to half decade, it is possible to adjust the EQUAL Control at one point in a half decade in such a way that the variation of the 90^{o} signal amplitude is ± 9% (see Figure 2.2) from this value and this pattern will be repeated in every other half decade. The frequency to make this adjustment is approximately .84 or .36 of the maximum frequency of the half decade. This will limit the maximum error to ± 2.5^{o} at the 45^{o} position of the DEGREES Phase Dial. The error will be less at other positions of the DEGREES Phase Dial.

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90° Signal Amplitude Characteristics

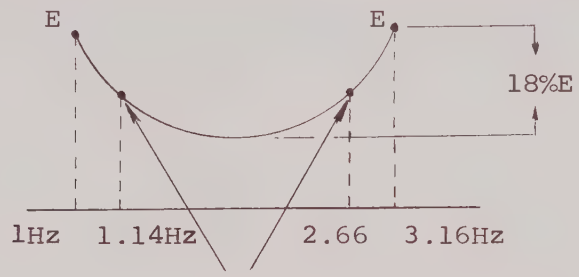

Figure 2.2

FILTER OPERATION

General

Due to the potential errors in making phase measurements on signals containing significant harmonics, it is normally necessary to use harmonic filters to achieve the ultimate accuracy of this measurement. It is also sometimes desirable to make non-phase sensitive measurements on input signals after removing noise and harmonic components. Therefore, provision is made for switching filters into both channels using the FILTER IN-OUT Switch while making both phase sensitive and non-phase sensitive measurements.

The filters used are plug-in, low pass types. The filters are operated in a restricted portion of the pass band in order to maintain, over this band, the amplitude gradient within the instrument specification and to restrict the phase variation. It will then be possible at any frequency within the band (see below) to make adjustments in the FILTER OUT position and switch to the FILTER IN position without having to make any further adjustment.

Two types of filters have been available for the Model 301A Their identification and salient features are shown in Table 2.1. The newer filter, designated as the Series F21, is an improved version, which supercedes the

older types (P/N 782281-X). Their use results in: greater bandwidth, higher harmonic rejection, and a few number of filters to cover the frequency spectrum (see Tables 2.2 and 2.3):

TABLE 2.1

Type	fa Band		fp Band	
	Bandwidth for 1% Amp. Grad.	3rd Harmonic Rev. at Lowest Frequency	Bandwidth for 2% Amp. Grad.	3rd Harmonic Rev. at Lowest Frequency.
782281 (Old type)	.87fm to 1.15fm BW=fm±15%	30db	.78fm to 1.25fm BW=fm±25%	20db
(782234) Series F21	.71fm to 1.41fm BW=fm±41%	30db	Not Rated	

Usable bandwidth limits are determined as follows:

f_m designates the geometric mean frequency of the usable band.

Upper frequency limit is determine by the amplitude vs. frequency characteristic. Lower frequency limit is determined by the amount of rejection of the third harmonic of this frequency.

Bands designated f_a ($.87f_m$ - $1.15f_m$) will have a maximum amplitude variation of 1% over the frequency band and 30DB* rejection of the third harmonic of $.45f_o$. (f_o is the frequency where the amplitude is down 6DB* from the low frequency amplitude.

*NOTE: When making phase sensitive measurements, the detector circuit inherently has a high second harmonic rejection (approximately 55DB) and 10DB additional rejection of the third harmonic.

This additional harmonic rejection is, therefore, added to the filter rejection when operating in any phase sensitive mode.

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Table 2.2 is a complete listing of the 782281 series with Figure 2.3 showing a typical characteristic curve for these filters. Table 2.3 is a complete listing of the F21 series(P/N 782234) with Figure 2.4 showing a typical characteristic curve for these filters.

Usable band limits were determined by the same criteria as the 782081 series. f_m designates the geometric mean frequency of the usable band. The usable band in this case, however, is not designed in the same manner. The upper limit is designated and is determined by $1.41f_m$ with a maximum amplitude variation of 1% over the frequency band. The lower limit is designated and determined by $.71f_m$ with a minimum rejection of 30DB of any frequency in the band.

It is possible to extend the range of any filter if additional attenuation is desired. If this is done, the filter adjustments described on the following page must be made at each frequency used, and the usable bandwidth around this frequency is correspondingly limited. It is not recommended that a frequency of $1.62f_m$ be exceeded.

NOTE: In general the instrument without filters has inherent harmonic rejection (see Pages 3.14 through 3.19). Therefore, the harmonic rejection with filters is the sum of the filter rejection described above and and the instrument rejection described on Pages 3.14 through 3.19.

The filters used in this instrument are supplied as matched pairs. These pairs are identified by the same serial number appearing on both. The serial number is located just beneath the North Atlantic nameplate. In order to insure optimum performance, these filters should always be installed as a matched set.

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Filter Adjustment

Open the meter door and insert desired filters into octal sockets.

Amplitude Adjustment:

a. Put in any convenient level of input signal at the f_m frequency of the filter.

b. Place FUNCTION switch in the VM position.

c. Turn FILTER IN-OUT Switch to OUT position.

d. Turn RANGE Switch to range corresponding to an on-scale reading with signal input available.

e. Observe the reading on the meter. This should be as close to full scale as possible.

f. Switch to FILTER IN position and adjust R105, Filter Level Adjustment, for the identical reading observed in Paragraph d. This control is mounted on the right side of the meter door behind the voltmeter.

g. No futher adjustment need be made in R105.

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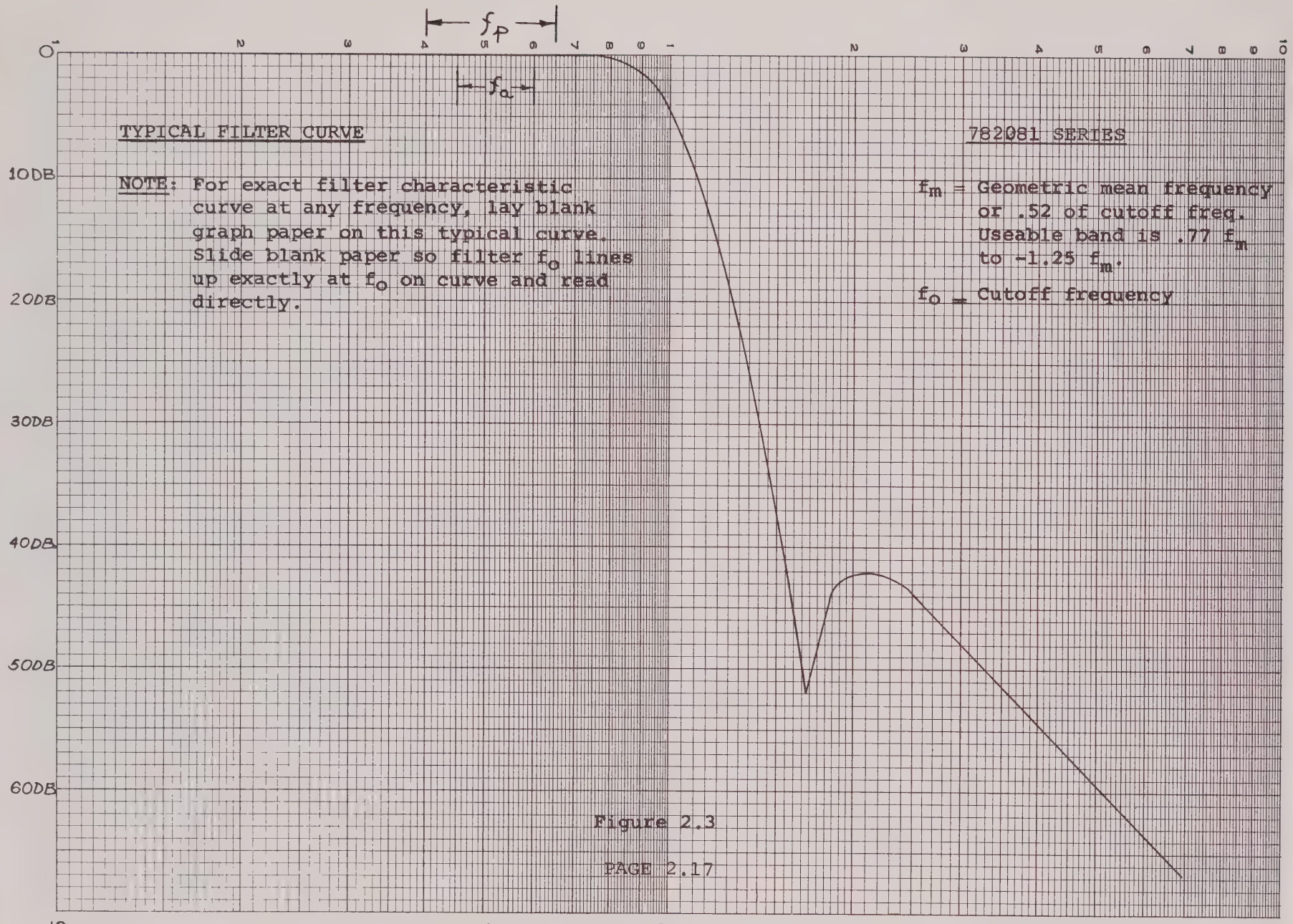
f_p
f_o
TYPICAL FILTER CURVE
NOTE: For exact filter characteristic curve at any frequency, lay blank graph paper on this typical curve. Slide blank paper so filter f_o lines up exactly at f_o on curve and read directly.
782081 SERIES
f_m = Geometric mean frequency or .52 of cutoff freq. Useable band is .77 f_m to -1.25 f_m.
f_o = Cutoff frequency
10DB
20DB
30DB
40DB
50DB
60DB
.1f_o
f_m
f_o
5f_o

Figure 2.3

TABLE 2.2

PART NO.	fm	f_a (.87f_m-1.15f_m)	f_p (.78f_m-1.25f_m)
782081-2	52.0	45 to 60	40 to 65
782081-3	62.5	54 to 72	48 to 78*
782081-4	83	72 to 96	64 to 104
782081-5	104	90 to 120	82 to 130*
782081-6	130	113 to 150	101 to 162
782081-7	156	136 to 180	122 to 195*
782081-8	260	225 to 300	200 to 325
782081-9	208	180 to 240	162 to 260
782081-10	416	360 to 480	325 to 520
782081-11	520	450 to 600	400 to 650*
782081-12	346	300 to 399	270 to 432*
782081-13	780	680 to 900	620 to 975*
782081-14	675	585 to 780	520 to 845
782081-15	1.04KC	900 to 1200	820 to 1300
782081-16	1.56KC	1360 to 1800	1220 to 1950
782081-17	2.08KC	1800 to 2400	1620 to 2600
782081-18	2.6KC	2260 to 3000	2050 to 3250
782081-19	1.3KC	1125 to 1500	1015 to 1620*
782081-20	3.12KC	2725 to 3575	2430 to 3900*
782081-21	5.2KC	4500 to 6000	4000 to 6500*
782081-22	4.15KC	3600 to 4750	3240 to 5200
782081-23	6.11KC	5300 to 7000	4750 to 7600
782081-25	7.8KC	6800 to 9000	6200 to 9750*
782081-26	9.53KC	8250 to 11000	7400 to 11915

* This indicates filters which may be omitted when using f_p accuracy and still have complete frequency coverage.

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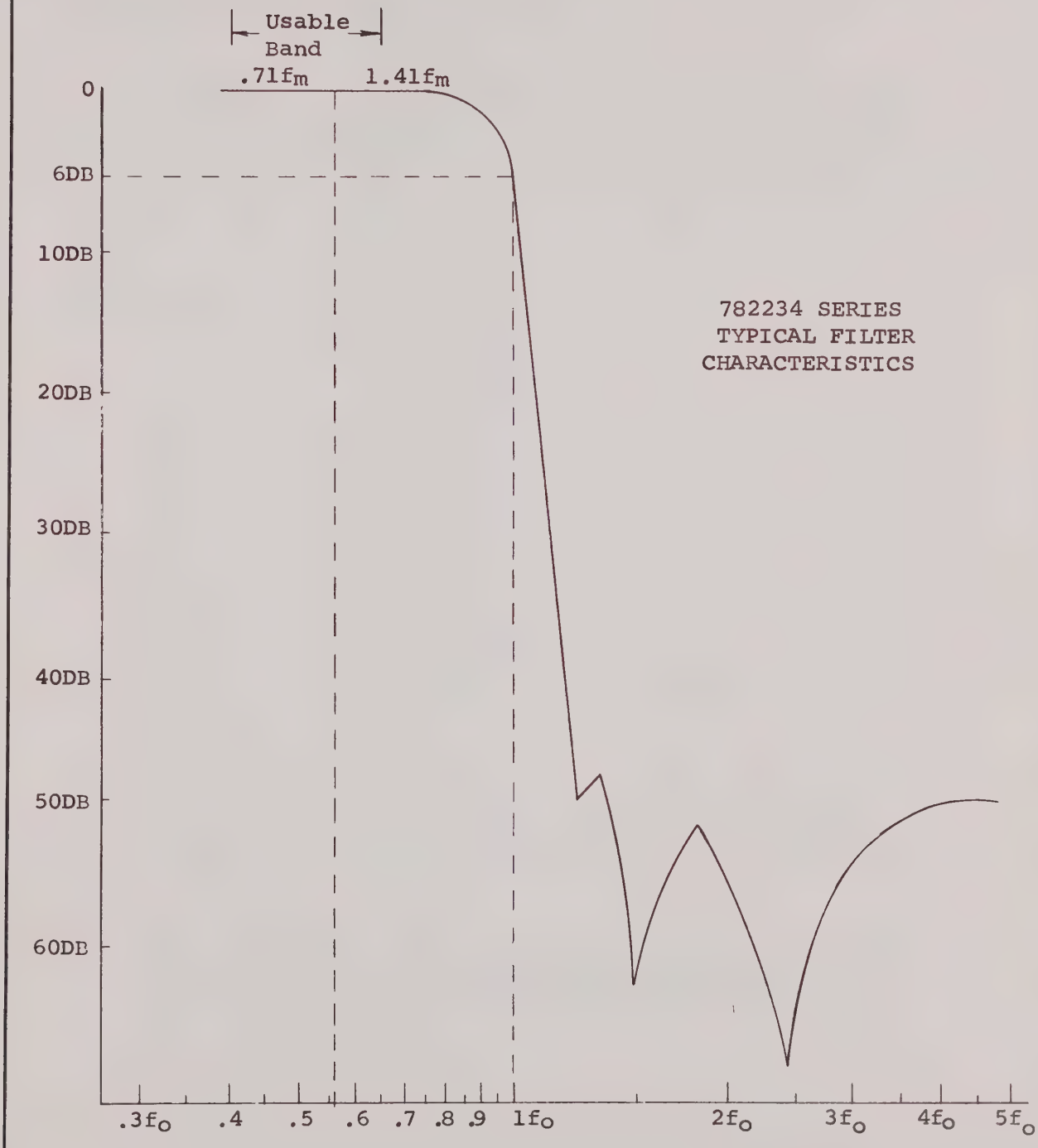

Figure 2.4

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TABLE 2.3

Model No.	Part No.	Usable Band	Remarks
FM-21-*	782334-11	27.5Hz to 55Hz	
FM-21-*	782334-1	55Hz to 110Hz	
FM-21-*	782334-2	110Hz to 220Hz	
FM-21-*	782334-3**	220Hz to 440Hz	
FM-21-*	782334-10	265Hz to 530Hz	
FM-21-*	782334-4**	525Hz to 1050Hz	
FM-21-*	782334-5	800Hz to 1760Hz	
FM-21-*	782334-6	1760Hz to 3520Hz	
FM-21-*	782334-7	3520Hz to 7040Hz	
FM-21-*	782334-8	7040Hz to 14.1KHz	
FM-21-*	782334-12	14.2KHz to 28.2KHz	

Filters may be specified either by NAI Part Nos.

or by Model Nos followed by the *Operating Frequency.

**NOTE: -3 Not recommended for 400Hz. Use -10
-4 Preferred for 1KHz.

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SECTION III

THEORY OF OPERATION

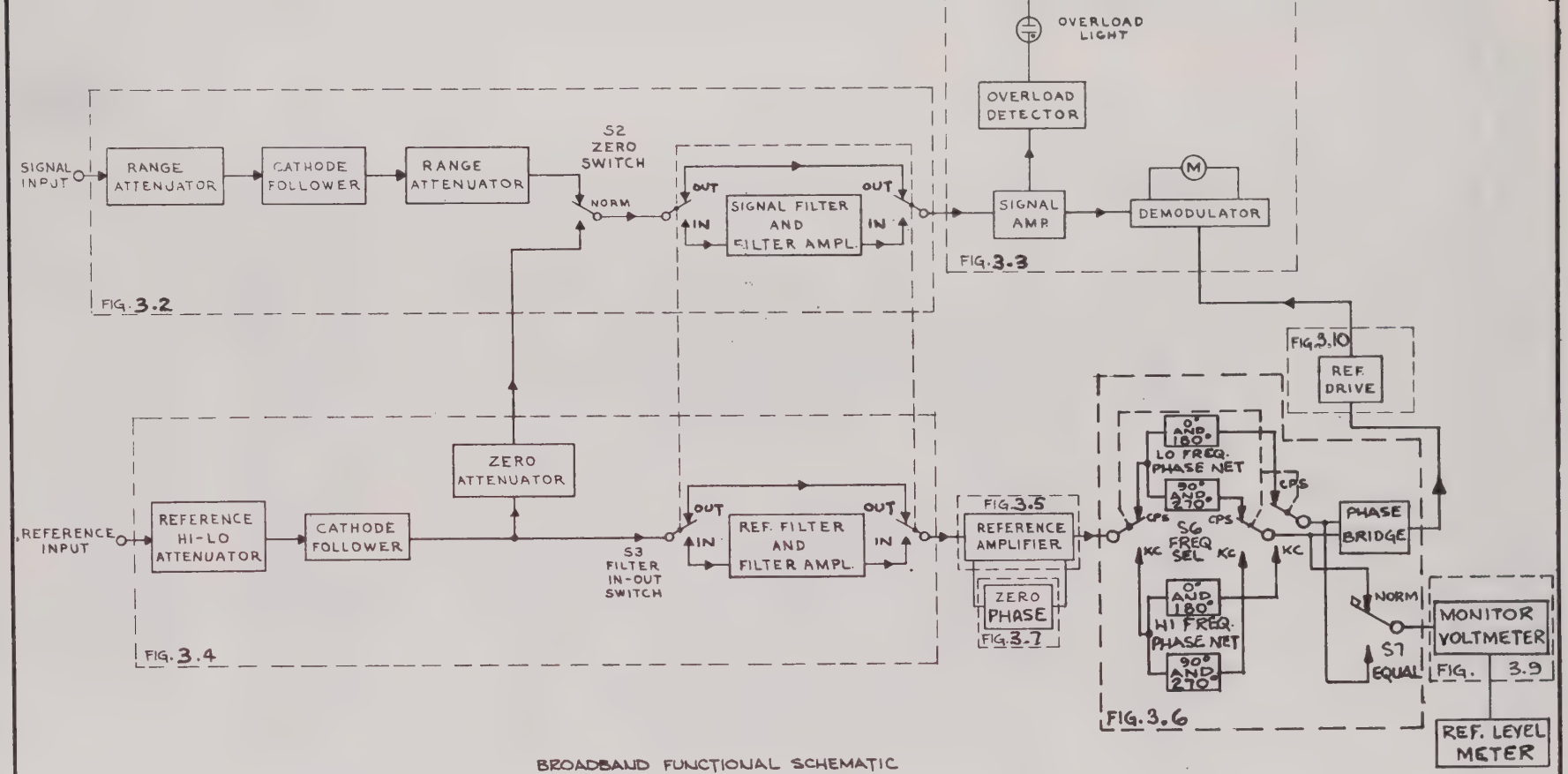
The functional schematic of Figure 3.1 will serve to illustrate the principle of operation of the Model 301A Broadband Phase Angle Voltmeter in its entirety. Note that detailed schematics showing all components are also included in Figures 3.2 through 3.11.

SIGNAL CHANNEL

Input Attenuator and Preamplifier (Figure 3.2)

The 1000:1 resistive divider feeds into the grid of cathode follower (V101). A six step voltage divider forms the cathode resistor for this tube. Connection for both of these attenuators is accomplished by the RANGE Switch (S1). For inputs from .001 to .3 volts, the signal is applied directly to the grid of V101. For inputs of 1 to 300V, the signal is attenuated by 1000:1. The six step divider switch section is arranged so that its rotor has two moving arms located 180° apart. As the RANGE Switch is rotated through its full range of rotary travel, contact is made twice with each of the six taps; once for the six low ranges; once for the six high ranges. On the six high ranges, the input signal is divided down before it is applied to the six step divider, each tap on the divider serves two ranges, giving a total of twelve ranges. Connections on both attenuators are arranged so that the output of the six step divider is maintained at approximately .001 volts which corresponds to full scale voltage for each range.

The RC Networks on the six step divider serve to reduce switching transients and maintain proper ratios at all frequencies. The 1000:1 attenuator is a broadbanded attenuator maintaining its ratio and zero phase over the



BROADBAND FUNCTIONAL SCHEMATIC

FIGURE 3.1

entire band of frequencies.

When no filters are employed, the cathode follower (V101) output is applied directly to the input of the main signal amplifier. When filters are used, the output of the cathode follower is applied by means of the Filter Switch to the second 6AB4 (V102). This stage operates as a low gain amplifier to supply the proper driving impedance for the filter, and to compensate for filter insertion loss. Amplitude recalibration of the voltmeter when changing filters is accomplished by potentiometer, R105. The adjustment is located on the meter door. The proper adjustment procedure for this calibration is described under "Filters."

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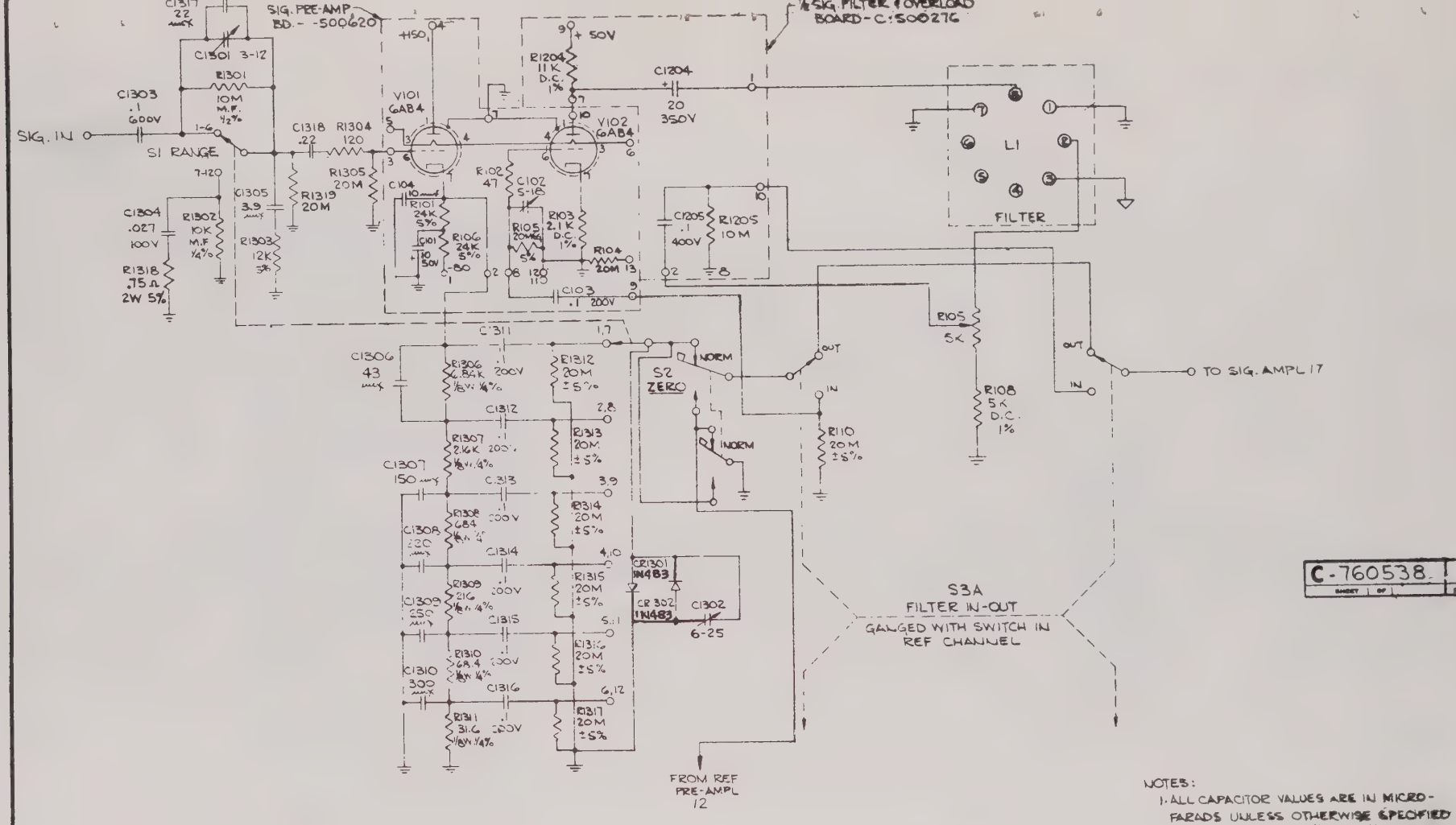

NOTES:

1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED
2. ALL RESISTORS ARE ½ W, ±10% UNLESS OTHERWISE SPECIFIED
3. See Fig. 4.1, page 4.6 for parts layout.

SIGNAL PREAMPLIFIER
Figure 3.2
Page 3.4

Revision A - 10/17/67
Revision B - 10/4/68
5/28/70

Signal Amplifier (Figure 3.3)

This four-tube amplifier provides high gain over a wide frequency range. The output of the amplifier drives the phase-sensitive detector and a circuit which indicates overload conditions. A high degree of stability is obtained by the use of negative feedback. The pentode section of the dual tube (V204) drives the detector and meter circuit. The amplifier feedback is returned from the plate of this tube through the meter rectified circuit to the cathode of the first amplifier tube (V201). The overall gain of the amplifier is adjusted by means of the calibration potentiometer (R242) located on the back panel of the voltmeter.

The second half of V204 is used to operate the overload circuit. The point at which the light illuminates is adjusted by means of potentiometer R1003 mounted on the chassis to the rear of the phase pot housing.

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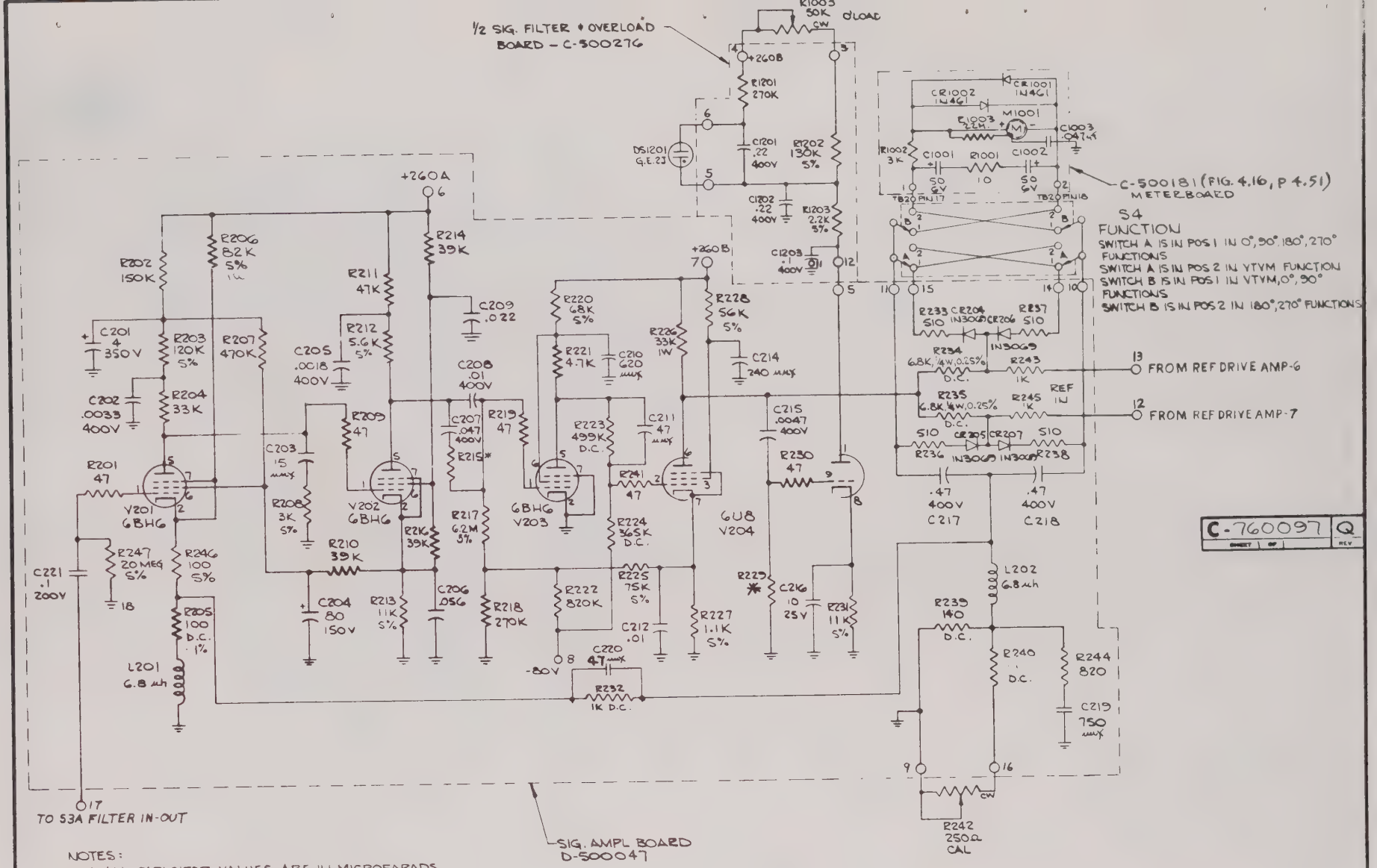

NOTES:
1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED
2. ALL RESISTORS ARE ½ W, ±10% UNLESS OTHERWISE SPECIFIED
3. See Fig. 4.2, page 4.12 for parts layout.

*Select at Test

SIGNAL AMPLIFIER
FIGURE 3.3
Page 3.6

Revision A - 10/17/67
Revision Q - 11/6/69
5/28/70

REFERENCE CHANNEL

Input Attenuator and Preamplifier (Figure 3.4)

A 30:1 resistive broadband divider feeds the grid of a cathode follower (1/2 of V301). A frequency compensated potentiometer forms the cathode resistor for the tube. The combination of these two attenuators allows the Reference Channel to be adjusted over the range of .15 to 150V input.

When no filters are employed, the cathode follower output signal is applied directly to the grid of the first reference amplifier tube (V401).

When a reference filter is used, the output of the cathode follower is applied, by means of the FILTER IN-OUT switch, to the second half of V301. This stage operates as a low gain amplifier to supply the proper driving impedance for the filter and compensates for the insertion loss in the filters.

Reference Amplifier (Figure 3.5)

This three tube amplifier supplies the necessary gain and low impedance output required for driving the phase shifting networks. Frequency response and phase shift characteristics are carefully controlled by compensating networks in the plate and cathode circuits. Negative feedback in the cathode of the input tube is passed through networks selected by the FREQUENCY Switch for proper frequency shaping. The second half of the input tube, operating as a phase shifter, feeds two cascaded push-pull stages.

The output stage, consisting of the two triodes, operates similar to a cathode follower with transformer coupled output. In order to cover the complete frequency band, one transformer is used for the low band and a different transformer is used for the high band. The proper unit is selected by the FREQUENCY Switch. The feedback network of this amplifier

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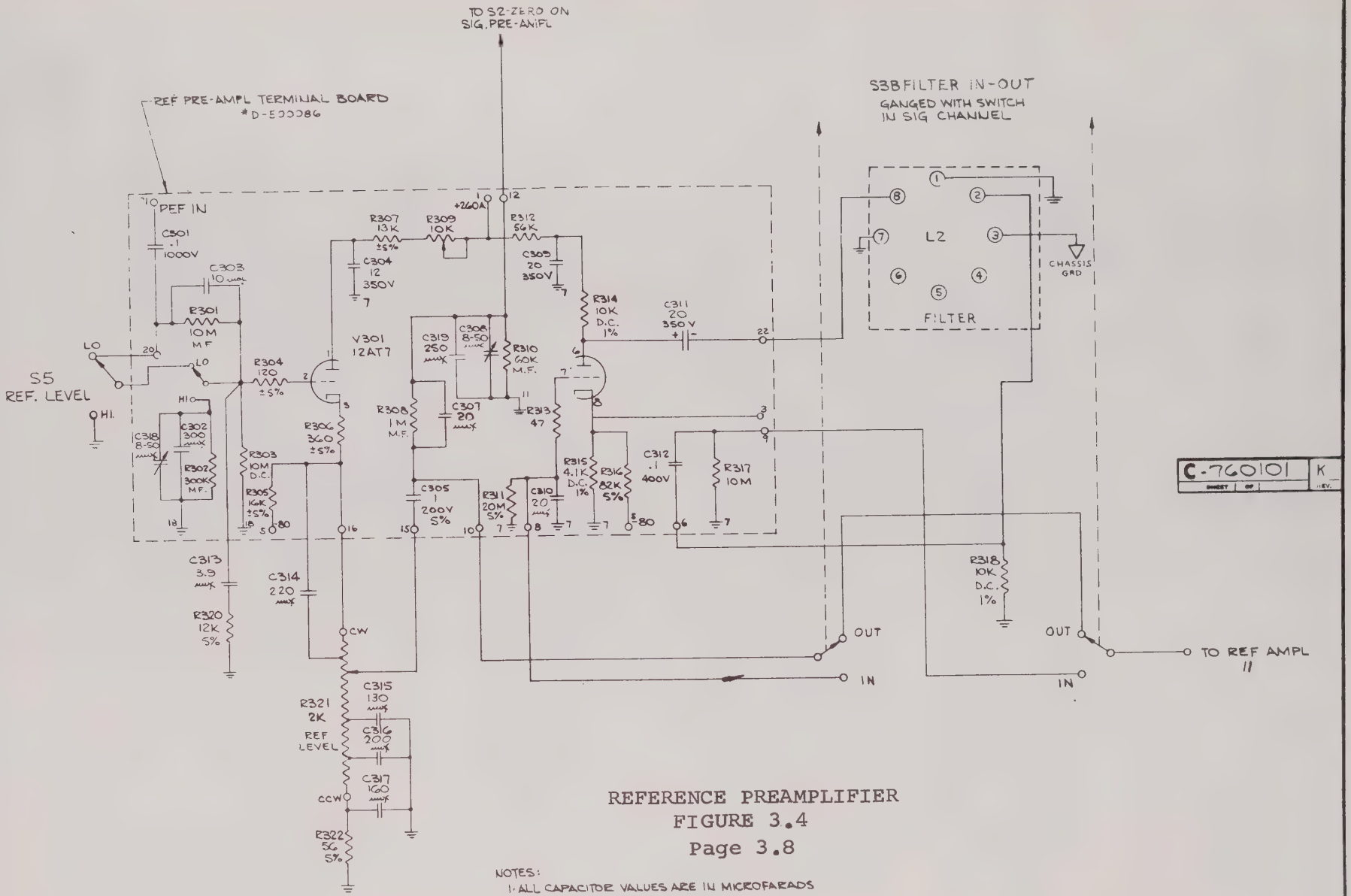
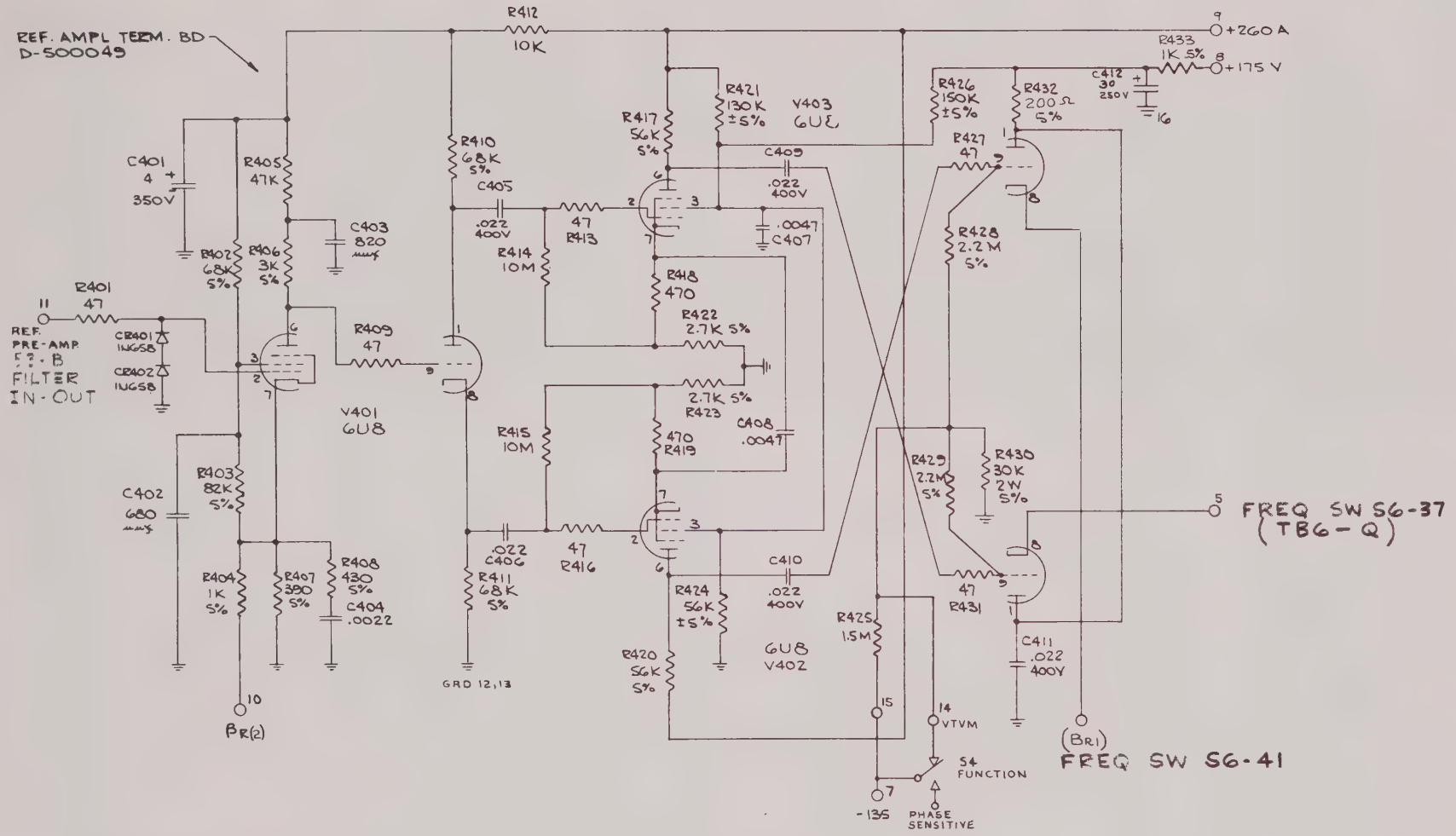


REFERENCE PREAMPLIFIER
FIGURE 3.4
Page 3.8

NOTES:
1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED
2. ALL RESISTORS ARE ½W. ±10% UNLESS OTHERWISE SPECIFIED

(See Figure 4.3 for parts layout)

5/4/70



NOTES:
1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED
2. ALL RESISTORS ARE ½W, ±10% UNLESS OTHERWISE SPECIFIED
3. SEE PAGE 5.2 FOR D.C. VOLTAGES

REFERENCE AMPLIFIER

FIGURE 3.5

See Figure 4.4 for parts layout

5/4/70

C-760098 · REV. C

is used to phase shift the entire Reference Channel when operating the ZERO Control. Proper capacitors are switched into this network as the FREQUENCY Selector is rotated, allowing plus and minus phase adjustments.

Phase Networks

A unique, patented, passive phase network design is used to establish +90° and -90° voltages. The 0° and 180° voltages which are derived from the center tapped secondary of the reference output transformer also represent the source for the phase networks. The four outputs resulting from this circuit configuration (0°, +90°, -90° and 180°) are applied to a resistive bridge, one leg of which is the calibrated variable DEGREES Phase Dial Potentiometer. By switching the potentiometer, with the FUNCTION Selector, between the 0° and 90° voltages and then between the 90° and 180° voltages, the instrument is switched into the 0° and 190° quadrants. By repeating the above procedure and reversing the meter, the instrument is then switched into the 180° and 270° quadrants.

ZERO and EQUAL Control

These controls, which are an integral part of the phase networks, perform trimming adjustment to compensate for the frequency and amplitude characteristic of the phase network and filters. Over such a large frequency range, it is inevitable that small differences in phase between the Signal and Reference Channel occur. On conventional phase angle measuring instruments, this difference is measured by connecting the reference signal into the Signal Channel. If this is to be done during a measurement, then it is usually necessary to readjust the RANGE Switch, FUNCTION Selector, and DEGREES Phase Dial to positions different from that used during the measurement. The ZERO Control on the Model 301A will automatically switch a portion of the reference through a broadband attenuator into the Signal Channel, at a level equivalent to a 6 x overload,

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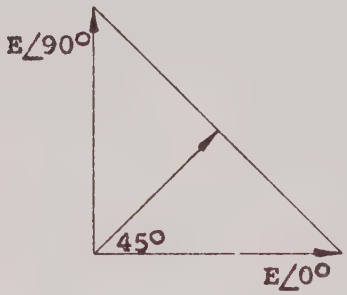

Figure 3.6a

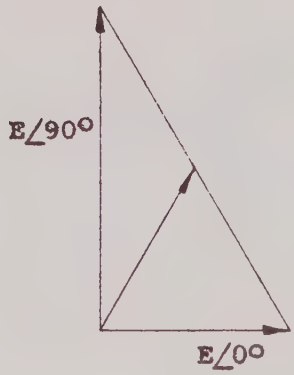

Figure 3.6b

Figure 3.6c

90° Signal Amplitude Characteristics

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independent of the position of the RANGE switch. This control will also switch the instrument into the 90° FUNCTION mode, independent of the position of the FUNCTION Selector or the DEGREES Phase Dial. Thus, one can make this adjustment, while making a measurement, without disturbing the instrument. The ZERO Control is a phase shifter in the Reference Channel, which is used to reduce the phase difference between the Signal and Reference Channels to zero. It is noted that the input sections of both Signal and Reference Channels contribute no phase error as a result of their careful circuit design.

The need for the EQUAL Control can be best illustrated by the vector diagrams shown in Figure 3.6. Figure 3.6a shows the vector voltage E that appears at the center of the phase pot when the 0° voltage is equal to the 90° voltage. It is apparent that the phase of this voltage is 45°. Figure 3.6b shows this same voltage at the center of the DEGREES phase potentiometer when the 90° voltage is much larger than the 0° voltage. It is evident that the phase of this voltage is no longer 45°. The error that exists at 45° (point of maximum error) is 0.28°/% difference of the two magnitudes. There is no error due to this effect at 0° or 90° on the DEGREES Phase Dial.

The 90° signal amplitude characteristics in each half decade of frequency follows the characteristic curve shown in Figure 3.6c for the 1KHz - 31.6KHz band. Thus, to ensure DEGREES Phase Dial accuracy at angles other than 0° and 90° the in-phase network amplitude must be adjusted so that it is equal to the 90° network amplitude. This is performed by measuring the 90° network amplitude on the monitor meter (Figure 3.7) while the EQUAL Switch is in its normal position. By depressing the EQUAL Switch, the in-phase amplitude is measured through the same monitor amplifier and meter and adjusted equal to the 90° amplitude.

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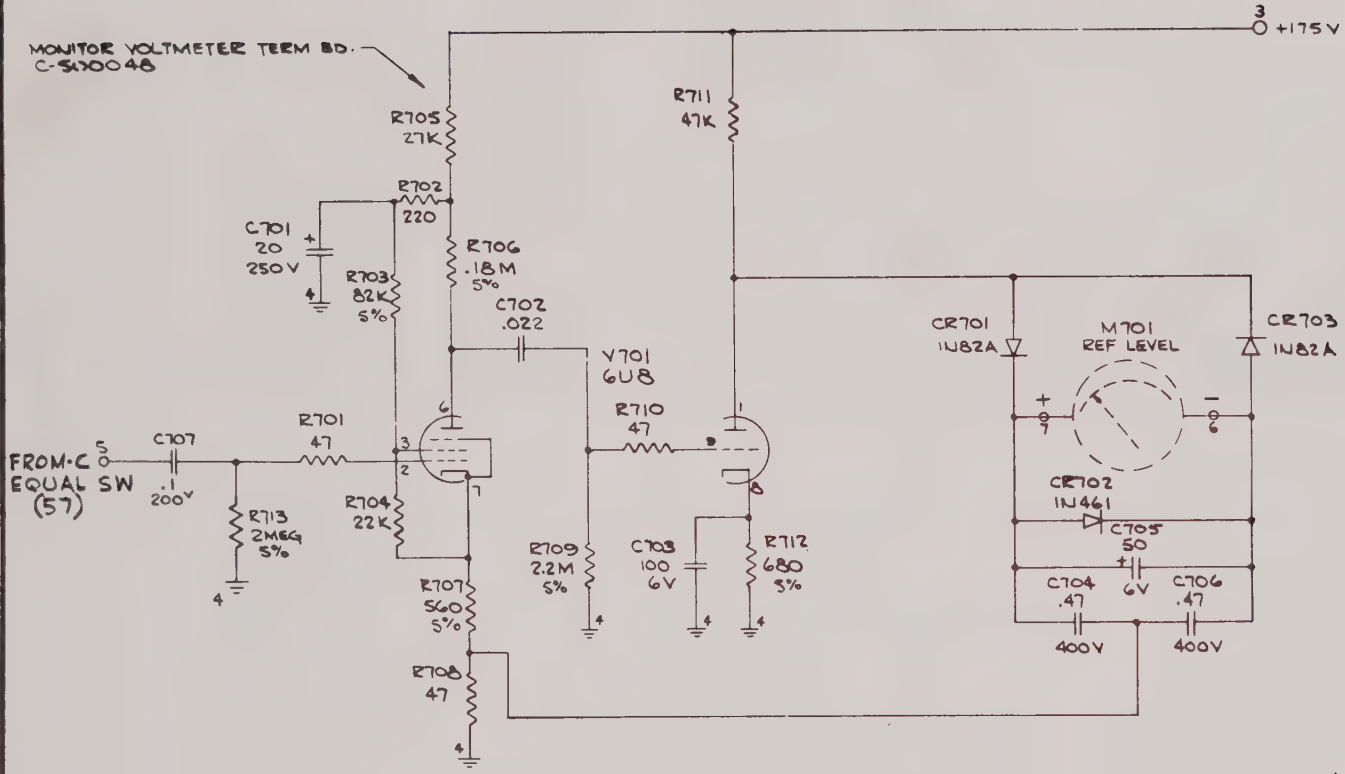

MONITOR VOLTMETER
FIGURE 3.7
Page 3.13

NOTES:
1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED
2. ALL RESISTORS ARE 1/2W, ±10% UNLESS OTHERWISE SPECIFIED
3. SEE PAGE 5.11 FOR D.C. VOLTAGES

(See Figure 4.13 for parts location)

5/4/70
6/30/70

Reference Drive Amplifier (Figure 3.8)

This amplifier receives the signal from the calibrated DEGREES phase potentiometer and drives the reference side of the phase-sensitive detector when the FUNCTION Switch is in any of the phase-sensitive positions (0° 90°, 180° or 270°). This amplifier is a wide-band, Highly-stabilized, phase-corrected amplifier. Its purpose is to drive the phase-sensitive demodulator without using a transformer as this would severely limit the frequency capability. The input signal is also inverted twice through V801 and V802 and fed back to the DEGREES phase potentiometer arm through C645 to unload the capacity to ground on the arm of the pot.

Phase Sensitive Rectifier

The Demodulator's phase-sensitive operation (see Figure 3.9) can be likened to that of a set of commutating switches. The reference signal alternately connects one side of the meter to ground through resistors R240 and R242, then the other end on the revese cycle of the reference. The signal is, therefore, synchronously rectified through the meter movement. When the reference and signal are in-phase (Figure 3.9A) the average value will be a maximum and the meter will read a maximum. When the signals are 90° apart, (Figure 3.9B) the average will be a zero and no reading will result. The equation governing this is:

$$I_{Meter\ (avg)} = K E \cos \theta$$

Where K = proportionality constant
E = RMS of signal
θ = angle between signal and reference.

Demodulator saturation effects will limit this characteristic equation to the designed levels for the instrument. For improved accuracy under special conditions, the reference level may always be raised to maximum reading on REFerence LEVEL meter for high signal levels. Measurements at the quadrature null point ($\alpha = 90^{\circ}$) are unaffected by saturation.

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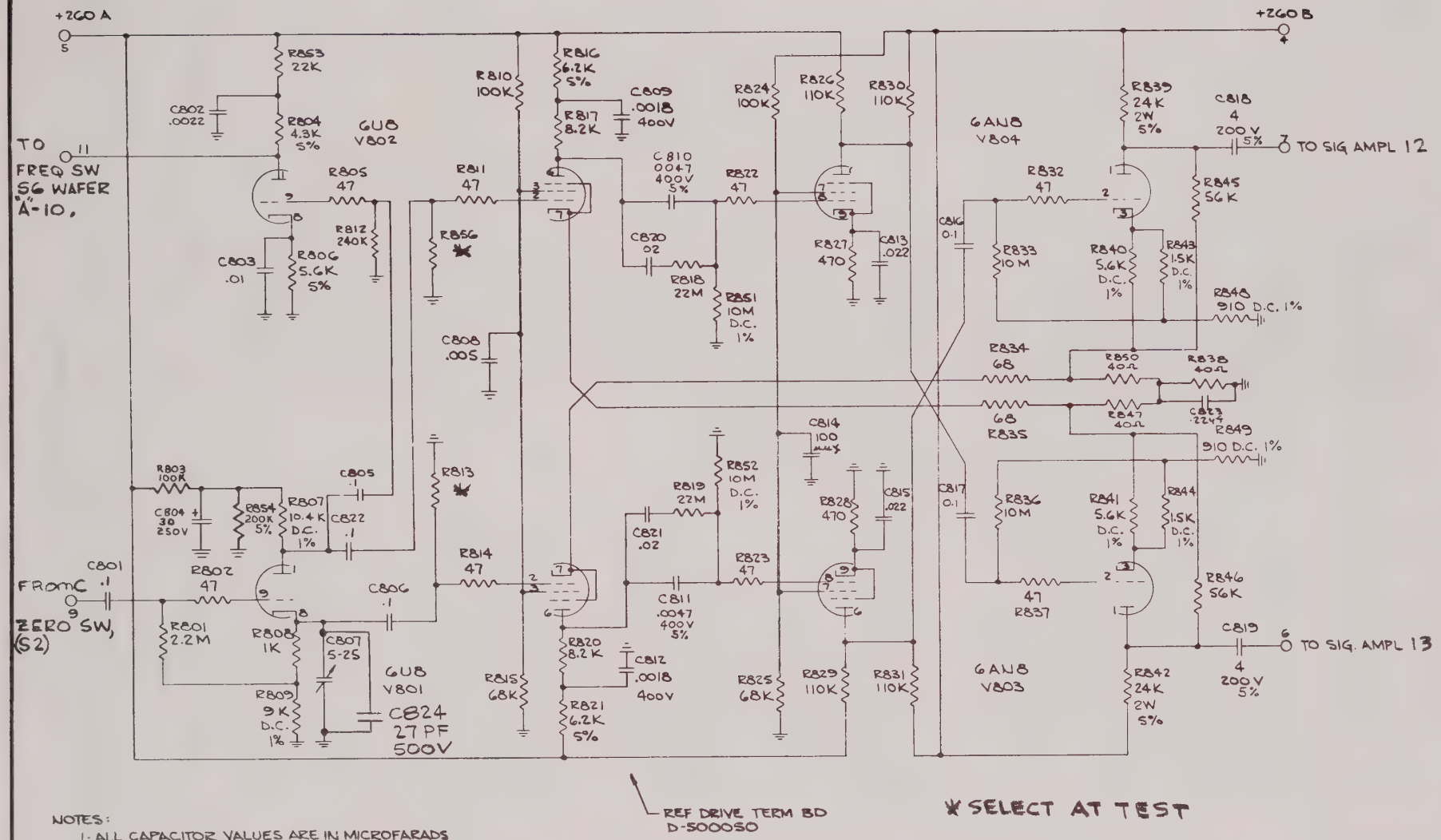


NOTES:
1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED
2. ALL RESISTORS ARE 1/2W, ±10% UNLESS OTHERWISE SPECIFIED
3. GRD PIN NO.'S 1,8 & 10
4. SEE PAGE 5.11 FOR D.C. VOLTAGES

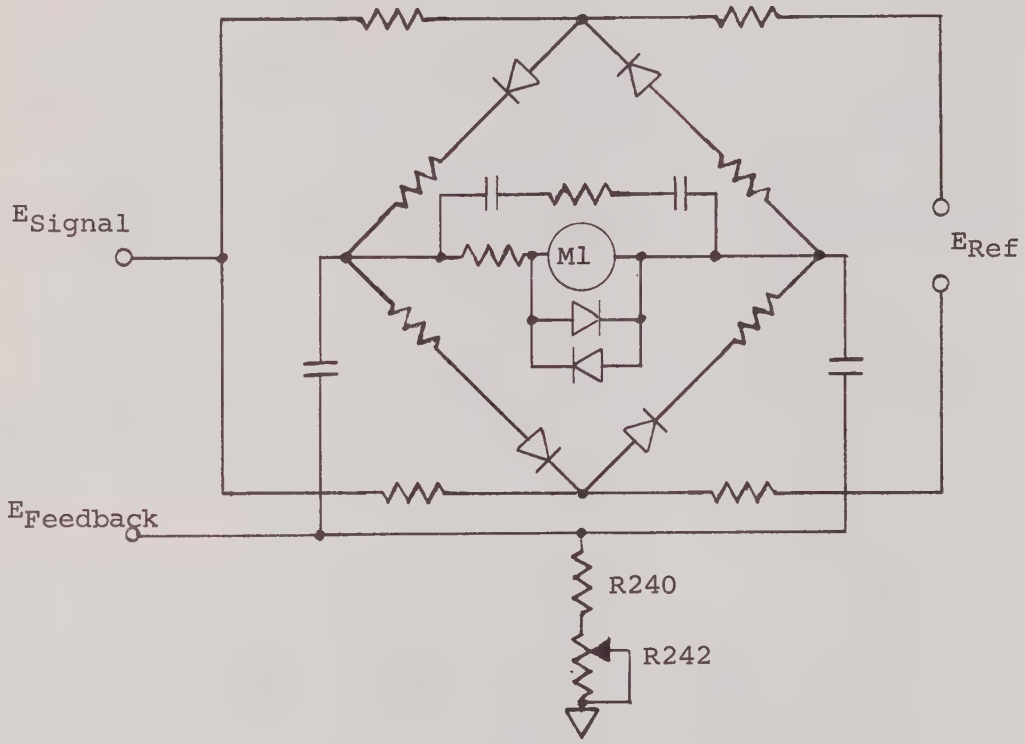
See Figure 4.14 for Schematic

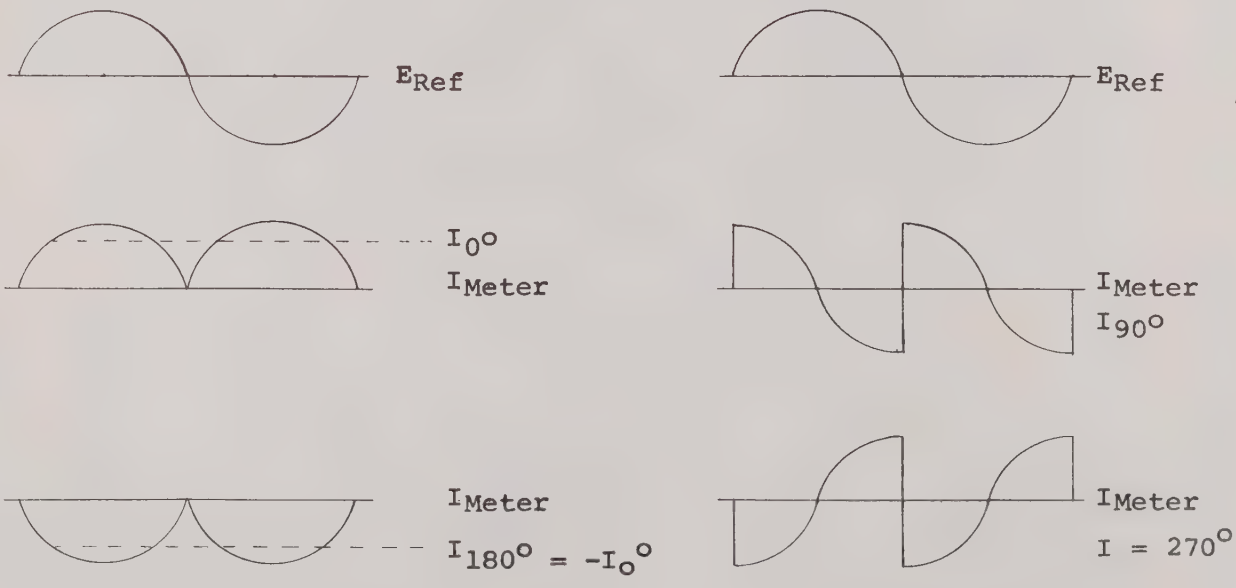
REFERENCE DRIVER AMPLIFIER

FIGURE 3.8

5/4/70
6/30/70

SIMPLIFIED PHASE SENSITIVE DEMODULATOR





IN PHASE (0°/180°)
(A)

QUADRATURE (90°/270°)
(B)

Figure 3.9

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The response of the phase sensitive detector is limited to signals at the reference frequency as well as to odd-order harmonics. All other frequencies are rejected, except for signals very near the reference frequency. Here, the meter movement will oscillate between plus and minus maxima at a rate equivalent to the difference between the signal frequency and the reference frequency. Response for this type detector to odd-order harmonics will never be greater than the fundamental response multiplied by a factor of 1/n where n is the order of the harmonic. In fact, it will usually be less and dependent upon the phase relation of the harmonic to the reference signal.

The effect of harmonics in the Reference Channel are of a different nature than of the Signal Channel. The resultant errors are due to phase shifts in the point at which the diodes start to conduct. Hence, second harmonic distortion can cause errors if the zero crossover of the second harmonic is not coincident with that of the fundamental. The most significant errors due to second and other even-order harmonic occur when the harmonic signals are present in both channels in phase with each other, and the harmonic phase are such that they peak when the fundamental is at zero crossing. Further, this error occur when the two channels are in quadrature relationship with each other and may be expressed as:

$\theta E_M = 2K_S K_R \times 57.3$

θE_M = Maximum angular error in degrees of Phase Dial

K_S = Ratio of 2nd harmonic to Fundamental in the Signal Channel ($K_S \times 100$ = % distortion).

K_R = Ratio of 2nd harmonic to Fundamental in the Reference Channel ($K_R \times 100$ = % distortion).

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For example, if 3% second harmonic distortion were present in both inputs in the most adverse phase relationship, the error would be 0.12^{o}. It is noted that errors due to second harmonic in the Reference Channel only are small and may be generally neglected except for very large values of distortion.

Third harmonics in the Reference Channel only may cause an error of K_R x 57.3 degrees in the relative phase of the reference if the harmonic peak when the fundamental is at zero crossing. For 3% distortion of this nature, an error of 1.7^{o} may result in Phase Dial reading.

In order to eliminate many of the above errors, when making accurate phase measurements, it is recommended that signal and reference filters be used.

Where a Signal Channel filter is used, there is, of course, essentially no response to harmonics in the Signal Channel.

When used as a conventional voltmeter, the phase-sensitive rectifier is switched to a full wave rectifier configuration. Operation is identical to that of a full wave bridge power supply in which the meter movement acts as the load.

Effects of Distortion

The current through the meter in the latter circuit is proportional to the average value of the voltage waveform applied. Calibration of the meter in RMS is based on a ratio between the average and effective values of a true sinesoidal voltage. Deviation from a true sinewave may cause errors in the meter indication. The Table lists the range of possible errors due to the 2nd and 3rd harmonic distortion.

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TABLE - Errors Due to Harmonics in a Typical Average Detector

Harmonic Order	Harmonic Content	Error
2nd	10%	Nil
2nd	20%	0 to +2%
2nd	50%	0 to +10%
3rd	10%	-4% to +4%
3rd	20%	-6% to +8%
3rd	50%	-10% to +16%

POWER SUPPLY

A special power supply is used in the Model 301A which meets the needs of the various amplifiers and circuitry throughout the unit. The particular voltages and regulation characteristics are specifically designed for use in the instrument. The schematic of Figure 3.10 shows its detail.

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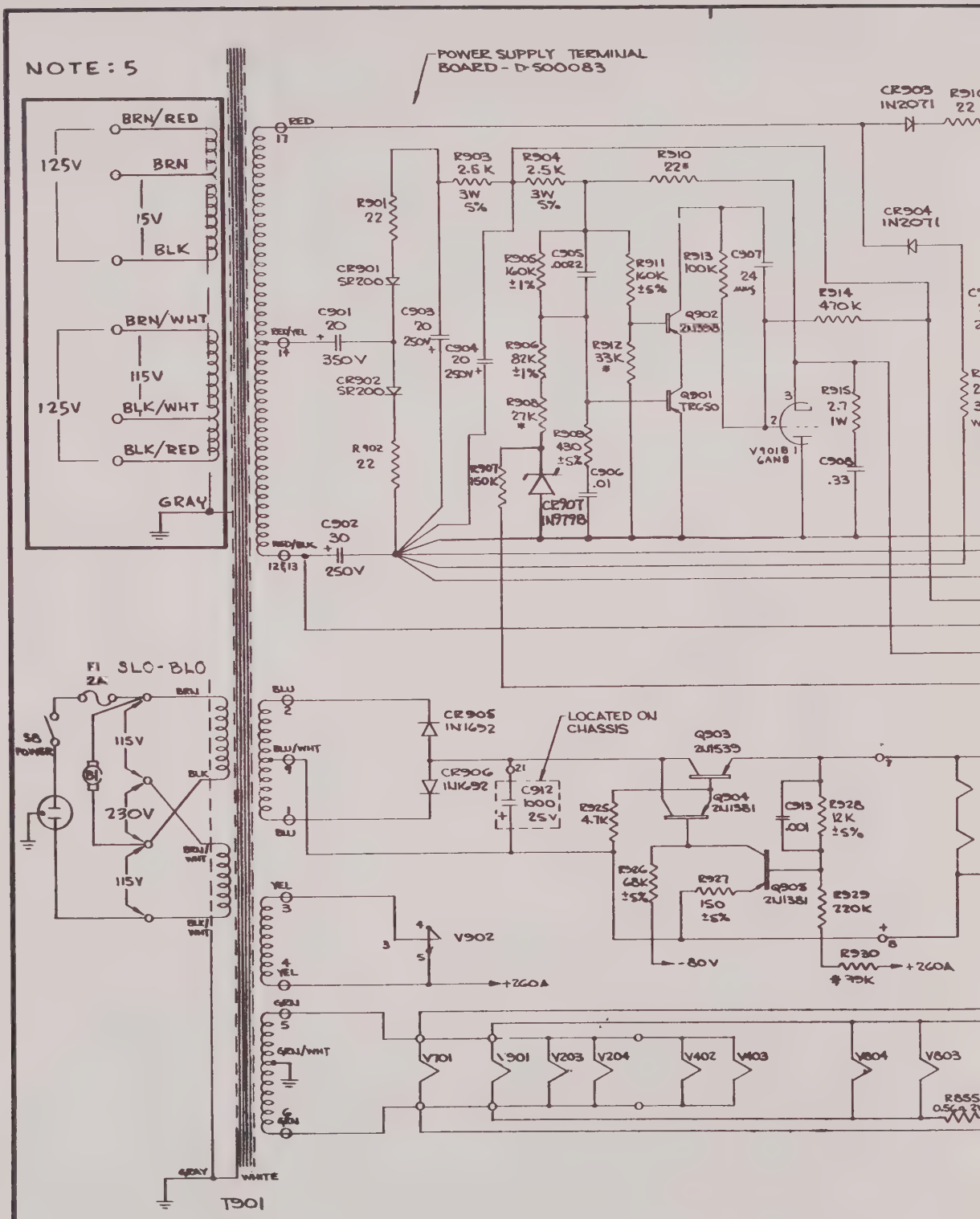
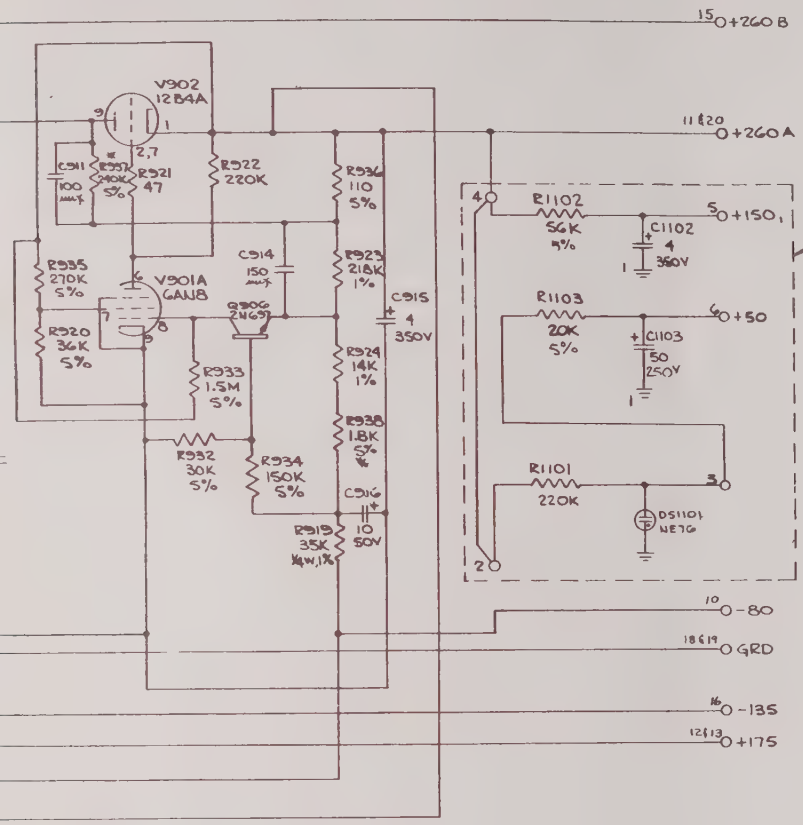
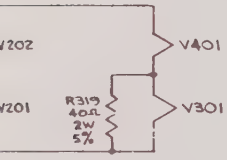
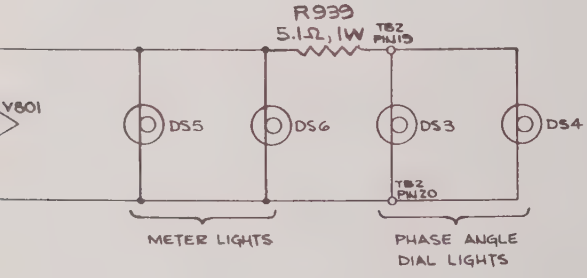

NOTE: 5
POWER SUPPLY TERMINAL BOARD - D500083
BRN/RED
125V
BRN
115V
BLK
BRN/WHT
115V
125V
BLK/WHT
BLK/RED
GRAY
RED
11
R901 22
R903 2.6K 3W 5%
R904 2.5K 3W 5%
R910 22Ω
CR903 IN2071
CR904 IN2071
R914 470K
C901 20 350V
C903 20 250V
C904 20 250V
CR901 SR200
CR902 SR200
R902 22
R905 160K ±1%
C905 .0022
R911 160K ±5%
R913 100K
C907 24 MFD
Q902 2N1308
R906 82K ±1%
R912 33K
R908 27K
R907 150K
R908 430 ±5%
C906 .01
CR907 IN777B
Q901 TRG50
R915 2.7 1W
V9018 1 6AN8
C908 .33
C902 30 250V
RED/BLK
12&13
F1 SLO-BLO 2A
SB POWER
115V
230V
115V
BRN
BLK
BRN/WHT
BLK/WHT
BLU
2
BLU/WHT
9
1
BLU
CR905 IN1692
CR906 IN1692
21
C912 1000 25V
LOCATED ON CHASSIS
Q903 2N1539
Q904 2N1381
R925 4.7K
R926 68K ±5%
R927 150 ±5%
Q905 2N1381
C913 .001
R928 12K ±5%
R929 220K
R930 # 75K
+260A
-80V
7
8
YEL
3
4
YEL
V902
+260A
GRN
5
GRN/WHT
6
GRN
V701
V901
V203
V204
V402
V403
V804
V803
R855
GRAY
WHITE
T901





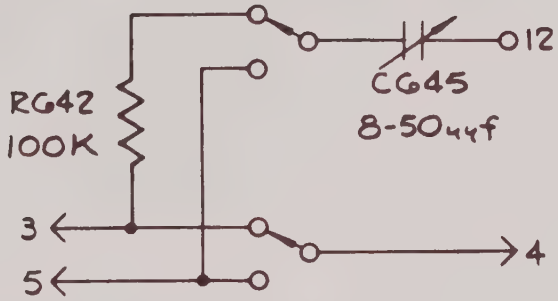


NOTES:

1. ALL CAPACITOR VALUES ARE IN MICROFARADS UNLESS OTHERWISE SPECIFIED.
2. ALL RESISTORS ARE ½W, ±10% UNLESS OTHERWISE SPECIFIED
3. C901, 902, 903, 909 & 912 ARE USED AS INPUT CAPACITORS WITH SILICON RECTIFIER
4. SEE PAGE 5.11 FOR D.C. VOLTAGES
5. Some instruments are equipt with alternate primary. See Fig. 2.1 for connection information.
6. See Fig. 4.15, Page 4.49 for parts Location.

POWER SUPPLY
FIGURE 3.10
Page 3.20

5/4/70
6/30/70



FREQUENCY SWITCH (S6)
WAFER "A"
FIGURE 3.11

A-7605G2

FREQUENCY SWITCH (S6) INTERCONNECTIONS

Pin #	Connects To	Pin #	Connects To
Bd-1- 1	Pin 64(S6)	39	Pin 10(S6)
2	R505-1(cw)	40	Pin 75(S6)
3	Pin 42(S6)	41	TB6-P
4	Pin 45(S6)	42	Pin 3(S6)
5	TB5-8	43	T602-1
6	Pin 70(S6)	44	T602-3
7	T601-6	45	Pin 4(S6)
8		46	Pin 60(S6)
9	S4 B9R	47	Pin 53(S6)
10	Pin 39(S6)	48	Pin 73(S6)
11	TB6-A	49	
12	TB6-B	50	Pin 59(S6)
13	R633-2		
14	R633-3		
15	TB6-D	BD-3-51	
16	TB6-C		
17		52	S4B9F
18	S4 A9R	53	Pin 47(S6)
19	R505-2	54	S7-NC
20	Ref Pre Amp Pin 1	55	Pin 38(S6)
21	TB5-13	56	T601-4
22		57	T602-4
23	R505-3(ccw)	58	S4-A9F
24	S4 B12F	59	Pin 50 (S6)
25	Pin 32(S6)	60	Pin 46 (S6)
		61	S4 B4R
BD-2 -26	Pin 65 (S6)	62	S4 A4R
27		63	
28		64	Pin 1(S6)
29		65	Pin 26(S6)
30		66	
31		67	
32	Pin 25(S6)	68	
33		69	T602-6
34		70	Pin 6(S6)
35	T601-1	71	Pin 40(S6)
36	T601-3	72	
37	TB6-Q	73	Pin 48(S6)
38	Pin 55(S6)	74	
		75	T601-5

Wafer "A"

Term.	Connects To
3	R644A-2
4	S2-NC
5	R644B-2
10	Ref Drive Amp 11

NOTE: Switch Code

B	4	R
Wafer	Term.	Rear

B	9	F
Wafer	Term.	Front

NOTE: See Figures 4.5 thru 4.12 for location of parts.

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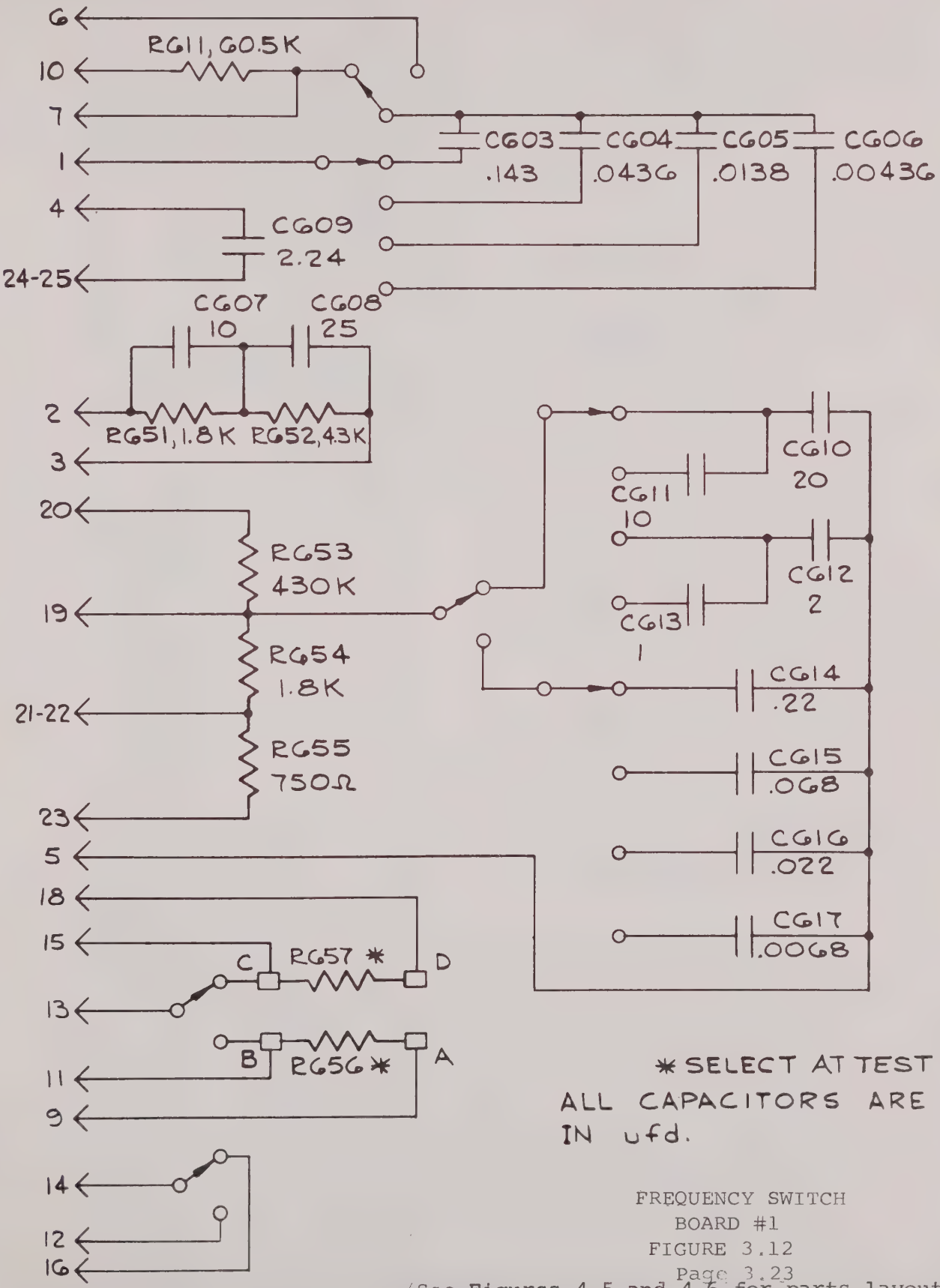
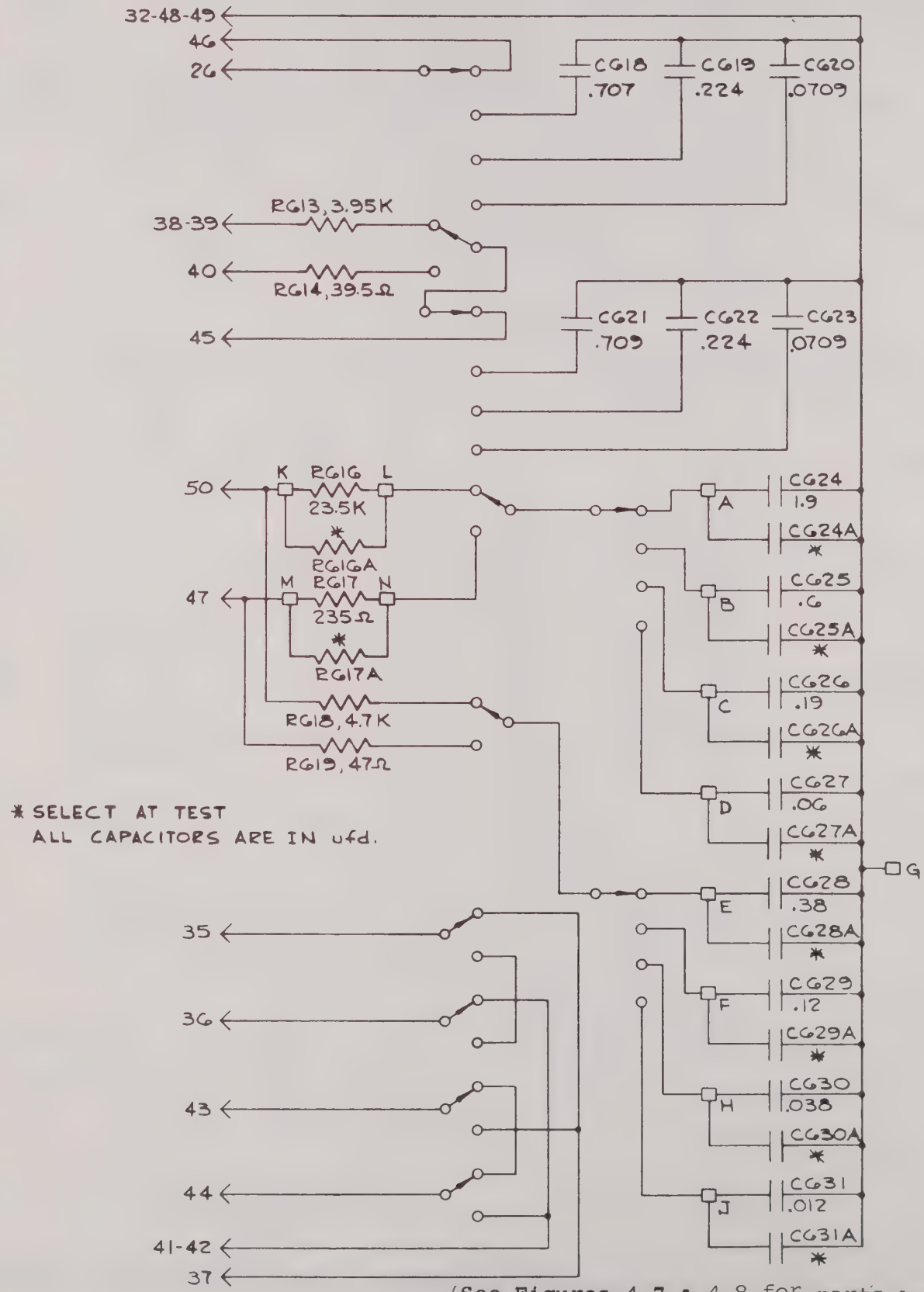


* SELECT AT TEST
ALL CAPACITORS ARE
IN ufd.

FREQUENCY SWITCH
BOARD #1
FIGURE 3.12
Page 3.23

(See Figures 4.5 and 4.6 for parts layout)

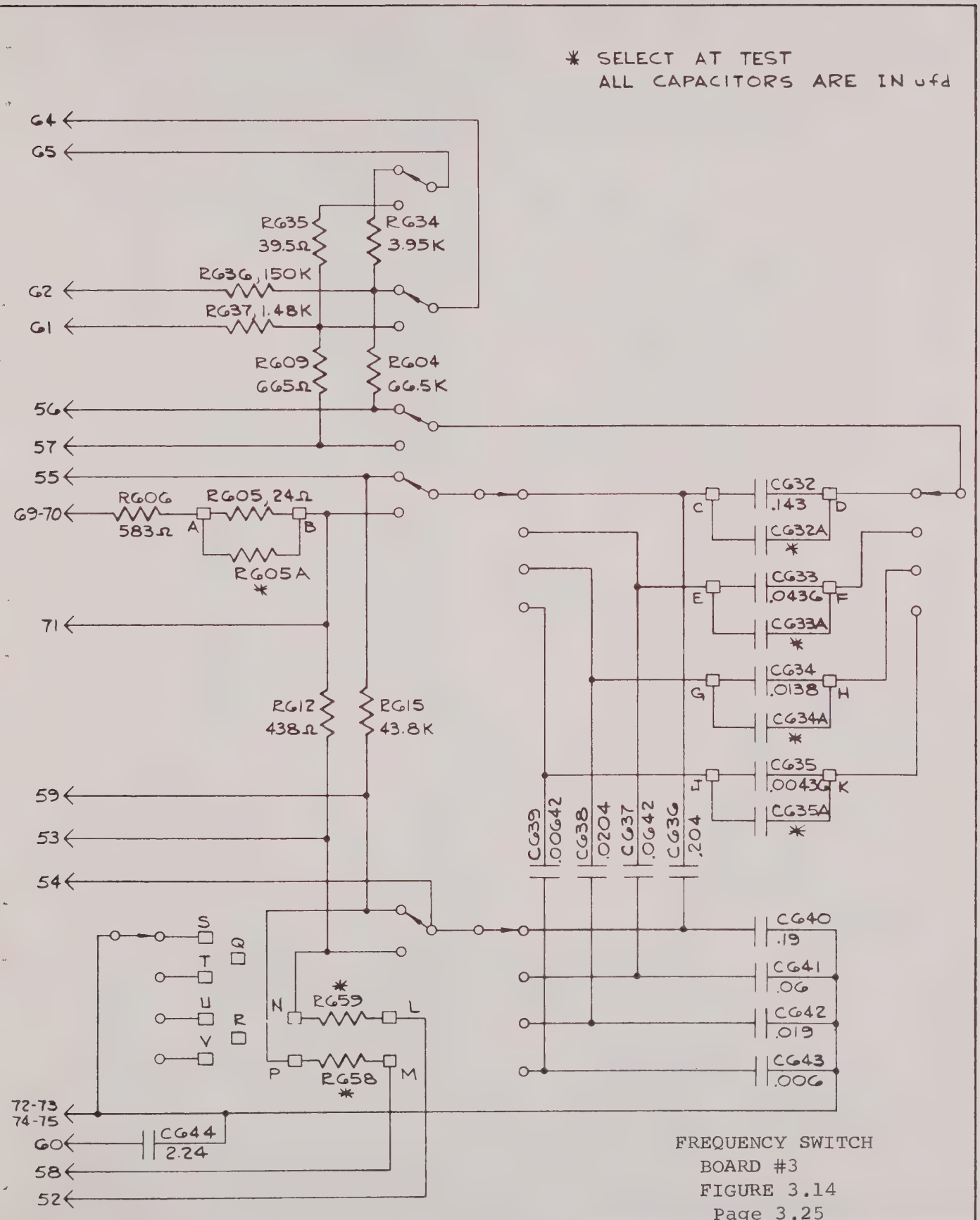
5/4/70



* SELECT AT TEST
ALL CAPACITORS ARE IN ufd.

FREQUENCY SWITCH - BOARD #2
FIGURE 3.13
Page 3.24

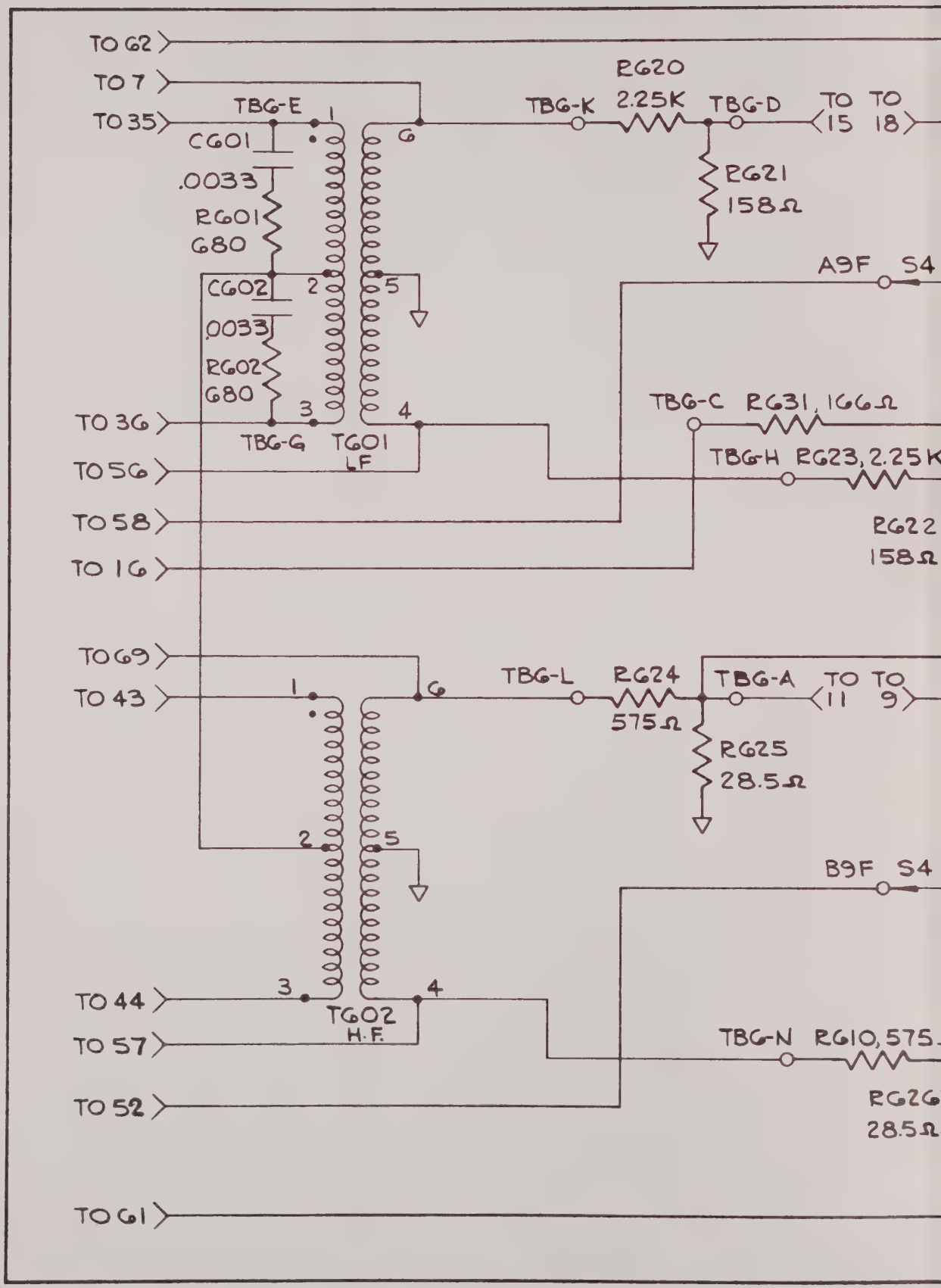
(See Figures 4.7 & 4.8 for parts layout)



FREQUENCY SWITCH
BOARD #3
FIGURE 3.14
Page 3.25

(See Figures 4.9 & 4.10 for parts layout)

5/4/70


TO 62
TO 7
TO 35
TBG-E
CG01
.0033
RG01
680
CG02
.0033
RG02
680
TO 36
TO 56
TO 58
TO 16
TBG-G
TG01
LF
TO 69
TO 43
TO 44
TO 57
TO 52
TG02
H.F.
TO 61
RG20
2.25K
TBG-K
TBG-D
TO TO
15 18
RG21
158Ω
A9F S4
TBG-C RG31, 166Ω
TBG-H RG23, 2.25K
RG22
158Ω
TBG-L
RG24
575Ω
TBG-A
TO TO
11 9
RG25
28.5Ω
B9F S4
TBG-N RG10, 575
RG26
28.5Ω

B-760559

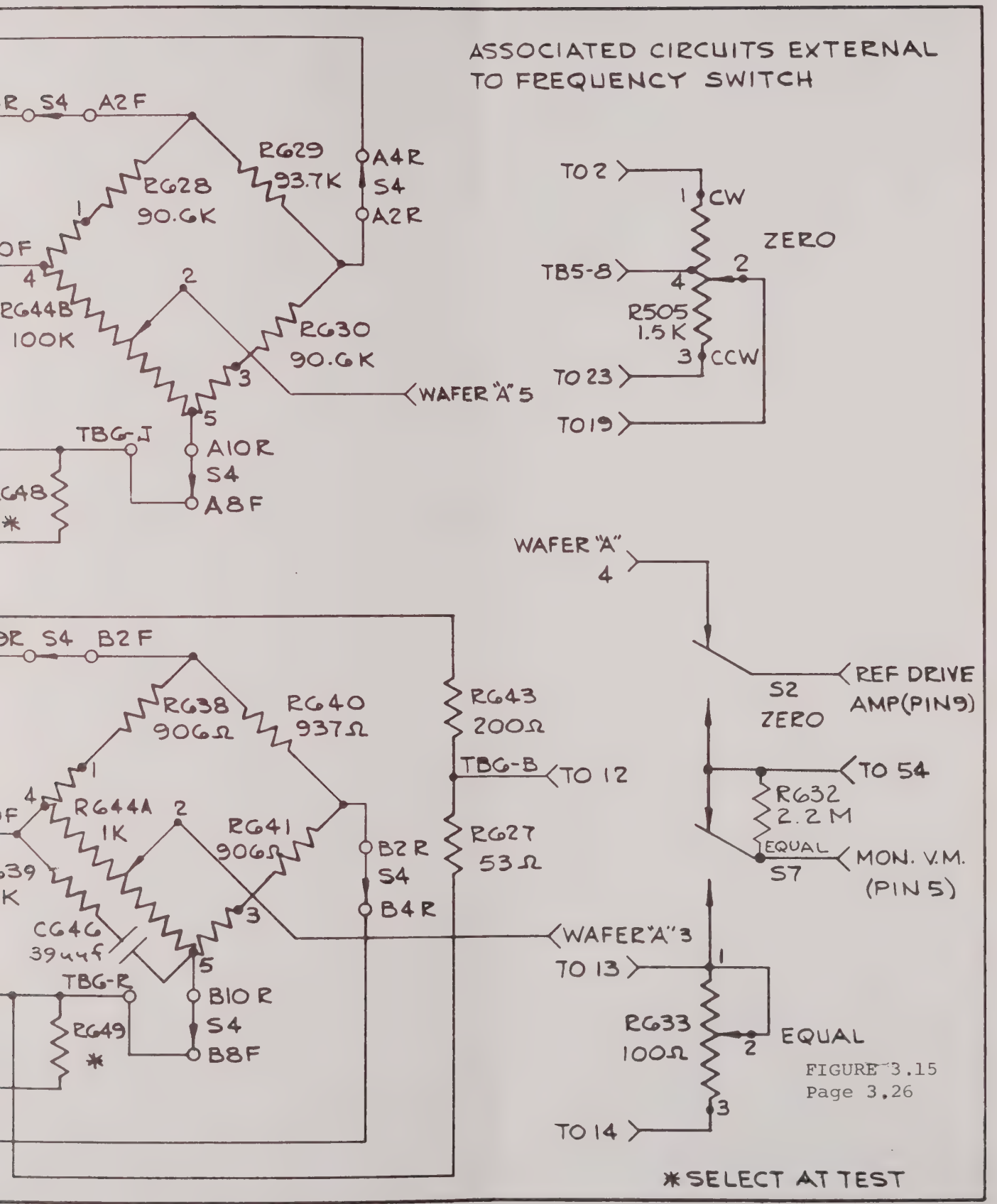


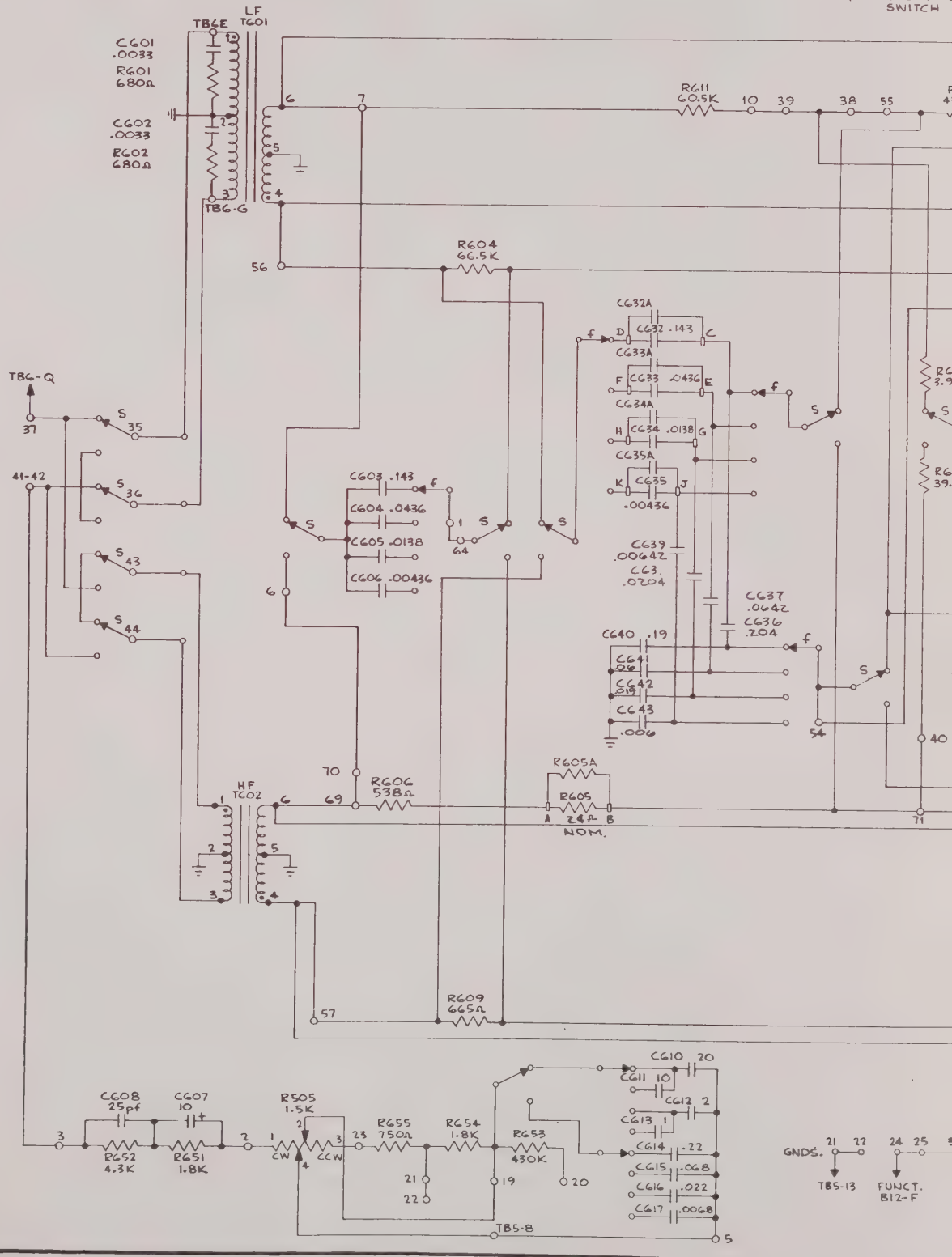
FIGURE 3.15
Page 3.26

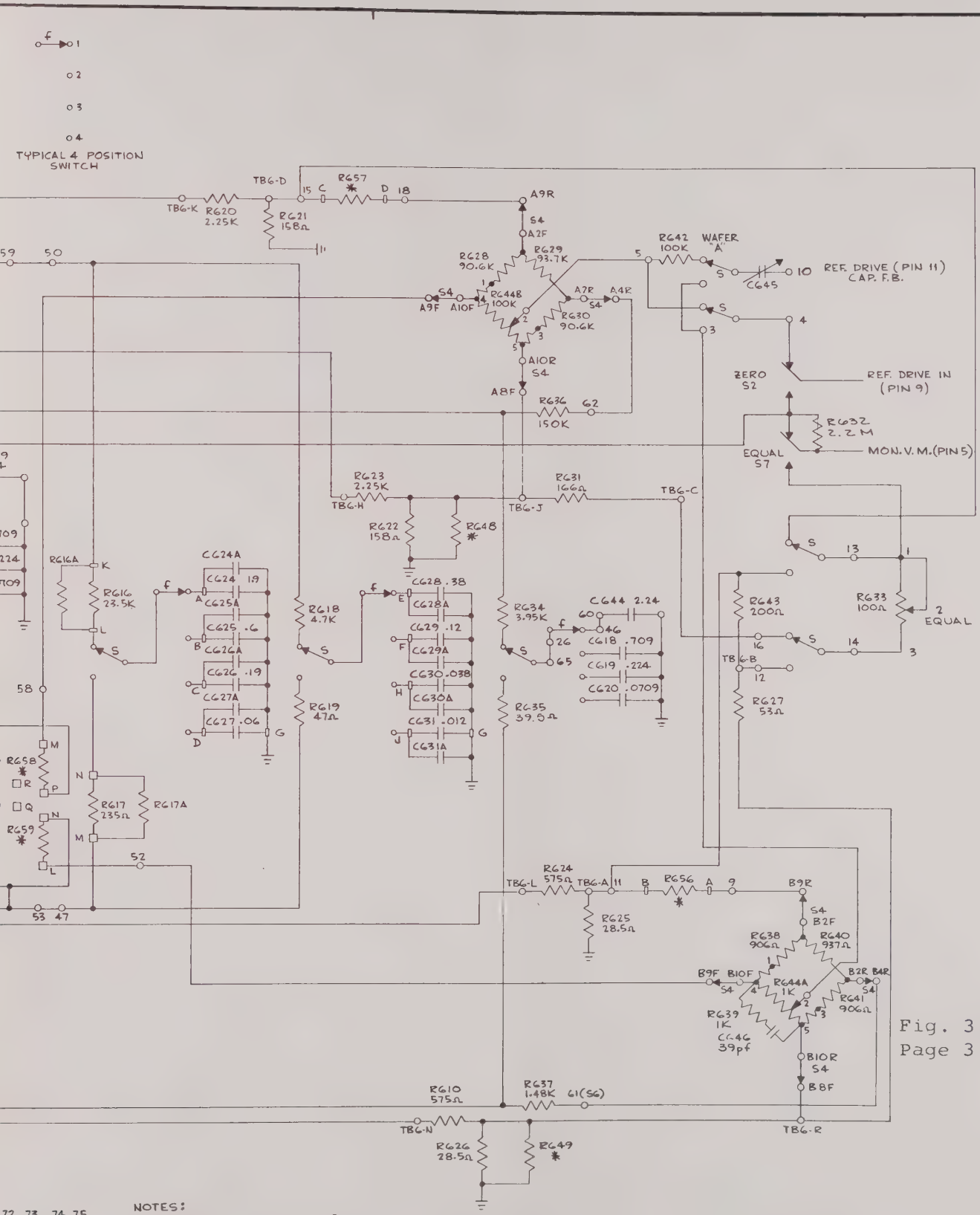
POSITION OF "S"	POSITION OF "F"	FREQUENCY BAND
1	1	10 - 31.6 CPS
1	2	31.6 - 100 CPS
1	3	100 - 316 CPS
1	4	316 - 1000 CPS
2	1	1 - 3.16 KC
2	2	3.16 - 10 KC
2	3	10 - 31.6 KC
2	4	31.6 - 100 KC

FREQUENCY SWITCH NOTES

1. ALL SWITCHES MARKED "S" & "F" ARE THE FREQUENCY SWITCH. (S6)
2. "S" IS THE SPECTRUM SWITCH AND HAS 2 POSITIONS "CPS" & "KC". SWITCH IS SHOWN IN "CPS" POSITION.
3. "F" IS THE FREQUENCY BAND SWITCH AND HAS 4 POSITIONS. THESE CORRESPOND TO THE BANDS OF FREQUENCY IN THE CHART.
4. S4 IS THE FUNCTION SWITCH.

TYPICAL 2 POS SWITCH





NOTES:
1. ALL CAPACITORS ARE IN ufd UNLESS OTHERWISE SPECIFIED.
2. * DENOTES SELECT IN TEST.
3. ALL CAPACITOR & RESISTOR DESIGNATIONS ENDING IN "A" REQUIRES SELECT AT TEST.

Fig. 3.16
Page 3.27

Phase Shift Networks

SECTION IV

MAINTENANCE

The following section contains instructions for the general maintenance of the Model 301A Broadband Phase Angle Voltmeter. Detailed alignment procedures are described in Section V It is recommended that alignment procedures be followed only if proper test equipment and sufficiently skilled personnel are available to perform the work.

CAUTION: High voltage exists at several points in the instrument. Normal precautions consistent with good practice should be taken to reduce shock hazard.

A potential shock hazard exists when ungrounded power source or ungrounded case operation is employed Persons operating the instrument should be made aware of and take precautions against this condition.

North Atlantic Industries, Inc. cannot be held responsible for damage to person or property in the process of or as a result of maintenance, calibration or setting up of the instrument.

COVER REMOVAL

A. Top and bottom covers are held in place by five screws each, and side covers are held in place by four screws each. Remove any set of these screws to allow removal of the corresponding top, bottom, or side covers.

B. To remove the back cover, remove the four screws at the sides of the back cover. For complete removal the fan mounting must be removed from the back panel itself.

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TUBE REPLACEMENT

CAUTION: DO NOT REMOVE TUBES FROM THE VOLTMETER BEFORE REMOVING POWER.

A. With the exception of V201 and V301, no circuit in the Model 301A is critical to tube replacement. However, for maximum accuracy the calibrations (as described in Section VII) should be checked following tube changing.

B. When replacing V201, it will be necessary to monitor the plate voltage of V202. This is at the top of R212 (5.6K, 1/2W Resistor) located directly under the V202 tube socket on the 500047 (Signal Amplifier) components board (Figure 4.2). A V201 (6BH6) tube should be chosen so that this voltage will be 150 ± 15 volts to ground, or trim R207 for 150 ± 15 volts after selecting a tube that will result in a voltage close to 150V.

C. When replacing V301, adjust DC voltage on Pin 16 of 500086 (Reference Pre-Amplifier) to equal zero with R309.

NOTE: Before changing the settings of any of the internal adjustments, check that the tubes are good.

REPLACEMENT OF PARTS

A. To remove and replace any of the tubes, it is necessary to remove the top or back covers of the instrument.

B. Most trouble shooting can be done by removing the top, bottom, and back covers. If it is desirable to inspect the boards mounted on the inside of the rear board panel or the terminal boards located under the power transformers, the inside rear panel may be dropped to a horizontal position. To accomplish this, first remove the two side covers. The screws at the top on either side of the inside rear panel must then be removed and the two screws at the bottom must be loosened.

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C. Although any component may easily be changed with the boards in place, should it be desirable to remove a board, remove the proper screws from the front of the board and unsolder the wires on the terminal lugs.

D. Several resistors in the voltmeter are precision components. If these resistors require replacement, use the same value and type as the original. If different values are used or components are moved, calibration or frequency response may be affected and readjustment may be required. Be careful to replace components as closely as possible to the same position the original components occupied. Pay careful attention to wiring and do not reroute or move any of the wires.

E. Transistors and semiconductor diodes are used throughout the instrument in the amplifiers, power supply, and meter circuit. If replacement is necessary, standard semiconductor practices are necessary. If any of the diodes in the meter circuits (CR204, CR205, CR206, CR207) are replaced, the voltmeter calibration, frequency, and phase calibration should be checked.

F. Panel lights in the meter are removable from the rear of the meter. They are made accessible by opening the meter door. The cap of the meter light assembly snaps into the knurled portion of the assembly. Do not attempt to remove the entire light assembly.

G. In the event it becomes necessary to replace the Phase Dial lights, see Figure 4.12 for replacement instructions.

H. The DEGREES Phase Dial of the Model 301A is driven by means of a dial cord. If the dial cord requires replacement, see Figure 4.19.

J. In the rare case where the DEGREES Phase Dial must be removed or replaced, it should be done in the following manner:

1. Remove front panel.
2. Remove dial cord, indicator bracket and lamp bracket.

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3. Remove dial from potentiometer shaft by loosening the set screws which hold it.
4. Replace dial on shaft (set screw should be tightened lightly at this point as the dial must be aligned with pot).
5. Replace indicator bracket, lamp bracket, and dial cord (See Figure 4.19)
6. Dial must now be aligned with potentiometer (See DEGREES Phase dial Alignment, Page 5.12)
7. Replace front panel.

K. The FREQUENCY Switch mechanism is described in Figure 4.5 thru 4.12. See Figures 3.12 thru 3.16 for the schematic diagrams of this circuit.

REFERENCE LEVEL METER REPLACEMENT

A. Remove top and left side covers.

B. Remove 2 flat head screws, which hold flat top plate, from top of sub-panel.

C. Remove screws holding left end of flat plate from left side of instrument.

D. Remove REFerence LEVEL meter mounting screws (top of meter).

E. Meter may now be lifted from its mount and leads disconnected.

F. Replace meter by following above instructions in reverse order, being careful to reconnect leads to same terminals.

FILTERS

The filters used in this instrument are supplied as matched pairs. These pairs are identified by the same serial number appearing on both. The serial number is located just beneath the North Atlantic nameplate. In order to insure optimum performance, these filters should always be installed as a matched set.

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REPLACEMENT PARTS LIST

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Signal Pre-Amplifier (Fig. 4.1)	500620	
C101	Capacitor, Fixed 10 ufd - 50V	802209	
C102	Capacitor, Variable 5-18 uufd	802547	
C103	Capacitor, Fixed .1 ufd - 200V	802220	
C104	Capacitor, Fixed 10uufd-500V ±10%	802422	
R101, 106	Resistor, Fixed, Comp. 24K-1/2W ±5%	800518	
R102	Resistor, Fixed, Comp. 47Ω-1/2W ±10%	800991	
R103	Resistor, Fixed D.C. 2.1K-1/2W ±1%	803065	
R104, 105	Resistor, Fixed, Comp. 20M-1/2W ±5%	801482	
V101, V102	Tube, Electron 6AB4	801070	

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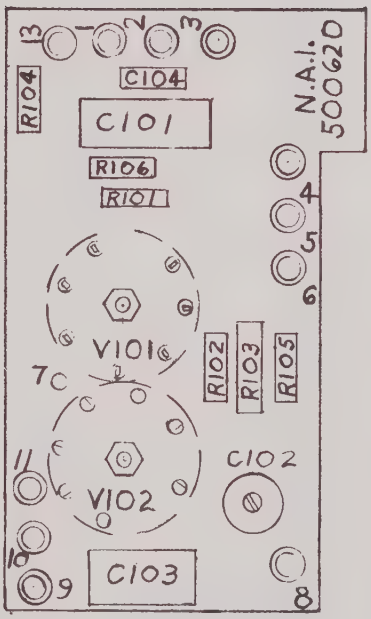

SIGNAL PREAMPLIFIER BOARD ASS'Y
#500620
Figure 4.1

(See Figure 3.2 for Schematic)

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REPLACEMENT PARTS LIST

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	ASSEMBLY, Signal Amplifier (Fig. 4.2)	D500047	
C201	Capacitor, Fixed, 4ufd, 350V	800888	
C202	Capacitor, Fixed, .0033ufd, 400V, ±10%	802265	
C203	Capacitor, Fixed, 15uufd, 500V, ±10%	801743	
C204	Capacitor, Fixed, 80ufd, 150V	801266	
C205	Capacitor, Fixed, .0018ufd, 400V, ±10%	802236	
C206	Capaictor, Fixed, .056ufd, 200V, ±10%	802222	
C207	Capacitor, Fixed, .047ufd, 400V, ±10%	802395	
C208	Capacitor,Fixed, .01ufd, 400V, ±10%	802237	
C209	Capacitor, Fixed, .022ufd, 200V, ±10%	802219	
C210	Capacitor, Fixed, 620uufd, 300V, ±10%	801746	
C221	Capacitor, Fixed, 47uufd, 500V, ±10%	801747	
C212	Capacitor, Fixed, .01ufd, 200V, ±10%	801879	

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11/7/69
11/17/69

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REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	ASSEMBLY, Signal Amplifier (Fig. 4.2)	D500047	
C214	Capacitor, Fixed, 240uufd, 500V, ±10%	801744	
C215	Capacitor, Fixed, .0047ufd, 400V, ±10%	802238	
C216	Capacitor, Fixed, 10ufd, 25V	801539	
C217,C218	Capacitor, Fixed, .47ufd, 400V, ±10%	800025	
C219	Capacitor, Fixed, 750uufd, 300V, ±5%	802315	
C220	Capacitor, Fixed, 47uufd, 500V, ±10%	801747	
C221	Capacitor, Fixed, .1uf, 200V	802220	
CR204,205, 206,207	Diode IN3069	802924	Fairchild
L201,L202	Choke 6.8uh	801742	
R201,209,219 230,241	Resistor, Fixed, Comp.,47Ω, 1/2W, ±10%	800991	
R202	Resistor, Fixed, Comp., 150K, 1/2W, ±10%	800057	
R203	Resistor, Fixed, Comp., 120K, 1/2W, ±5%	800869	
R204	Resistor, Fixed, Comp., 33K, 1/2W, ±10%	800839	

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REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Signal Amplifier (Fig. 4.2)	D500047	
R205	Resistor, Fixed, Dep. Carb., 100Ω, 1/2W, ±1%	801592	
R206	Resistor, Fixed, Comp., 82K, 1W, ±5%	804302	
R207	Resistor, Fixed, Comp., 470K, 1/2W, ±10%	800060	
R208	Resistor, Fixed, Comp., 3K, 1/2W, ±5%	800615	
R210, 214, 216	Resistor, Fixed, Comp., 39K, 1/2W, ±10%	801069	
R211	Resistor, Fixed, Comp., 47K 1/2W, ±10%	800087	
R212	Resistor, Fixed, Comp., 5.6K, 1/2W, ±5%	8000641	
R213, 231	Resistor, Fixed, Comp., 11K, 1/2W, ±5%	800620	
R215, 229	Resistor, Fixed, Comp., Select At Test		
R217	Resistor, Fixed, Comp., 6.2M 1/2W, ±5%	803708	
R218	Resistor, Fixed, Comp., 270K, 1/2W, ±10%	800059	
R220	Resistor, Fixed, Comp., 68K 1/2W, ±5%	800528	

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REPLACEMENT PARTS LIST

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Signal Amplifier (Fig. 4.2)	D500047	
R221	Resistor, Fixed, Comp., 4.7K 1/2W, ±10%	800078	
R222	Resistor, Fixed, Comp., 820K, 1/2W, ±10%	801598	
R223	Resistor, Fixed, Dep. Carb., 499K, 1/2W, ±1%	801597	
R224	Resistor, Fixed, Dep. Carb., 365K, 1/2W, ±1%	801596	
R225	Resistor, Fixed, Comp., 75K, 1/2W, ±5%	800090	
R226	Resistor, Fixed, Comp., 33K, 1W, ±10%	802260	
R227	Resistor, Fixed, Comp., 1.1K, 1/2W, ±5%	801595	
R228	Resistor, Fixed, Comp., 56K, 1/2W, ±5%	800857	
R232	Resistor, Fixed, Dep. Carb., 1K, 1/2W, ±1%	801136	
R233, 236, 237, 238	Resistor, Fixed, Comp, 510Ω, 1/2W, ±5%	800525	
R234, 235	Resistor, Fixed, Dep. Carb., 6.8K, 1/4W, ±0.25%	802802	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

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REPLACEMENT PARTS LIST

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Signal Amplifier Fig. 4.2	D500047	
R239, 240	Resistor, Fixed, Dep. Carb., 140Ω, 1/2W, ±1%	802376	
R243, 245	Resistor, Fixed, Comp., 1K, 1/2W, ±10%	800166	
R244	Resistor, Fixed, Comp., 820Ω, 1/2W, ±10%	800082	
R246	Resistor, Fixed, Comp., 100Ω, 1/2W, ±5%	800631	
R247	Resistor, Fixed, Comp., 20Meg, 1/2W, ±5%	801482	
V201, 202 203	Tube 6BH6	802285	
V204	Tube 6U8A	800028	

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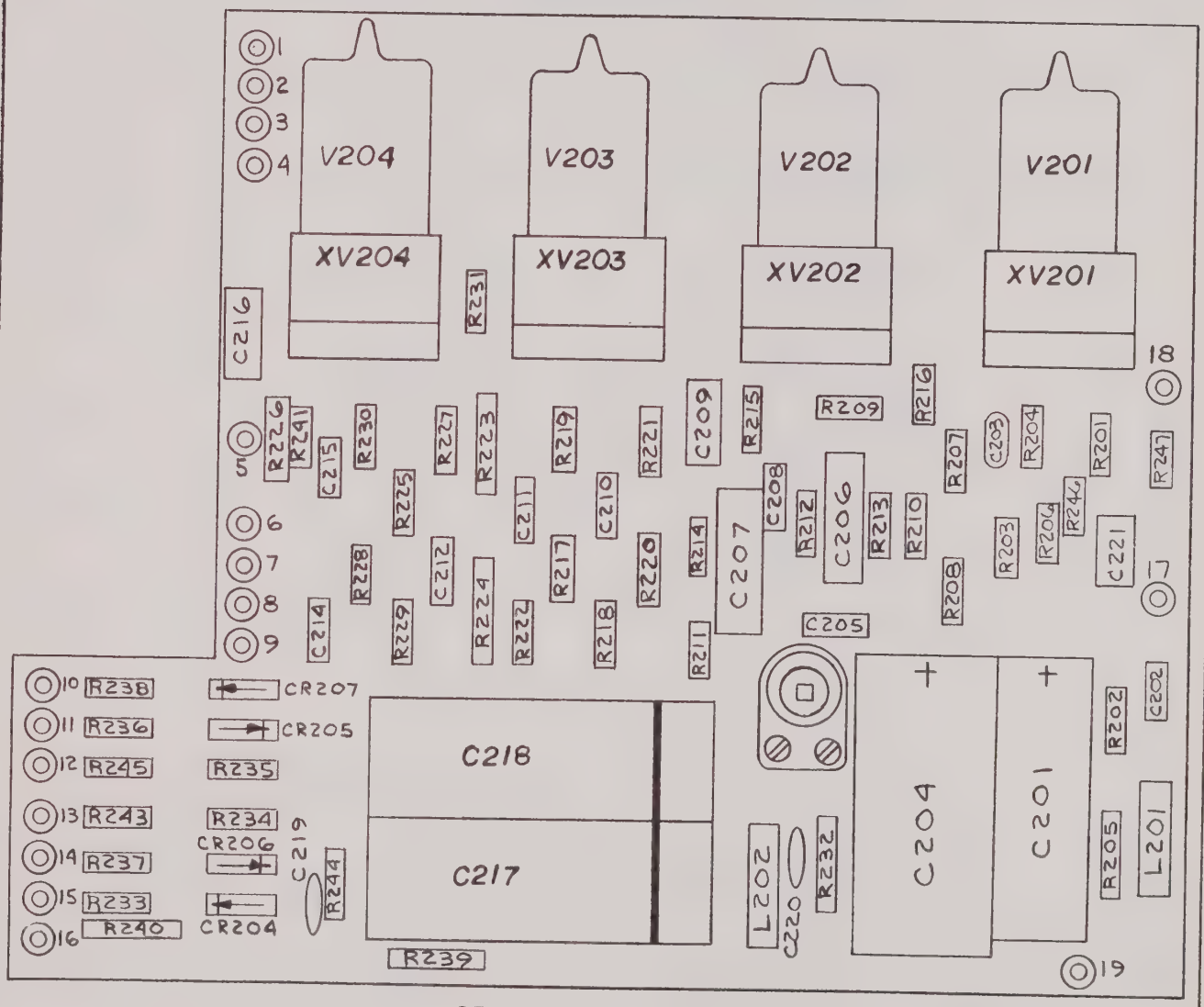

SIG. AMPL. BOARD ASSY.
500047

FIGURE 4.2

(See Figure 3.3 for Schematic)

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REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	ASSEMBLY, Reference Pre-Amplifier(Fig. 4.3)	D500086	
C301	Capacitor, Fixed, .1ufd, 1000V, ±10%	801068	
C302	Capacitor, Fixed, 300MMF, 500V, ±10%	802342	Special
C303	Capacitor, Fixed, 10uufd, 500V ±5%	802561	Special
C304	Capacitor, Fixed, 12ufd, 350V	801023	
C305	Capacitor, Fixed, 1ufd, 200V, ±5%	802794	
C307	Capacitor, Fixed, 20uuf, 500V, ±5%	802638	
C308, 318	Capacitor, Variable,8-50uufd	800854	Special
C309,311	Capacitor, Fixed, 20ufd, 350V	800847	
C310	Capacitor, Fixed, 24uufd, 500V, ±5%	802170	
C312	Capacitor, Fixed, .1ufd, 400V, ±20%	800020	
C319	Capacitor, Fixed, 250uufd, 500V, ±5%	802310	
R301	Resistor, Fixed, M.F., 10M, 1/2W, ±1%	802864	
R303	Resistor, Fixed, Dep., Carb., 10M, .75W, ±1%	802253	

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REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	ASSEMBLY, Reference, Pre-Amplifier (Fig. 4.3)	D500086	
R302	Resistor, Fixed, M.F., 300K, 1/2W, ±1%	802865	
R304	Resistor, Fixed, Comp., 120Ω, 1/2W, ±5%	800407	
R305	Resistor, Fixed, Comp., 16K, 1/2W, ±5%	800619	
R306	Resistor, Fixed, Comp., 360Ω, 1/2W, ±5%	801654	
R307	Resistor, Fixed, Comp., 13K, 1/2W, ±5%	800637	
R308	Resistor, Fixed, M.F, 1M, 1/2W, ±1%	802795	
R309	Resistor, Variable, 10K, 2W, ±10%	801750	
R310	Resistor, Fixed, M.F., 60K, 1/2W, ±1%	802796	
R311	Resistor, Fixed, Comp., 20M, 1/2W, ±5%	801482	
R312	Resistor, Fixed, Comp., 56K, 1/2W, ±10%	800498	
R313	Resistor, Fixed, Comp., 47Ω, 1/2W, ±10%	800991	
R314	Resistor, Fixed, Dep. Carb., 10K, 1/2W, ±1%	801481	

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REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO	MANUFACTURER
	ASSEMBLY, Reference Pre-Amplifier (Fig. 4.3)	500086	
R315	Resistor, Fixed, Dep. Carb., 4.1K, 1/2W, ±1%	802172	
R316	Resistor, Fixed, Comp., 82K, 1/2W, ±5%	801259	
R317	Resistor, Fixed, Comp., 10M, 1/2W, ±10%	801025	
R319	Resistor, Fixed, W.W., 40Ω, 2W, ±5%	802328	
V301	Tube, Electron, 12AT7	801019	

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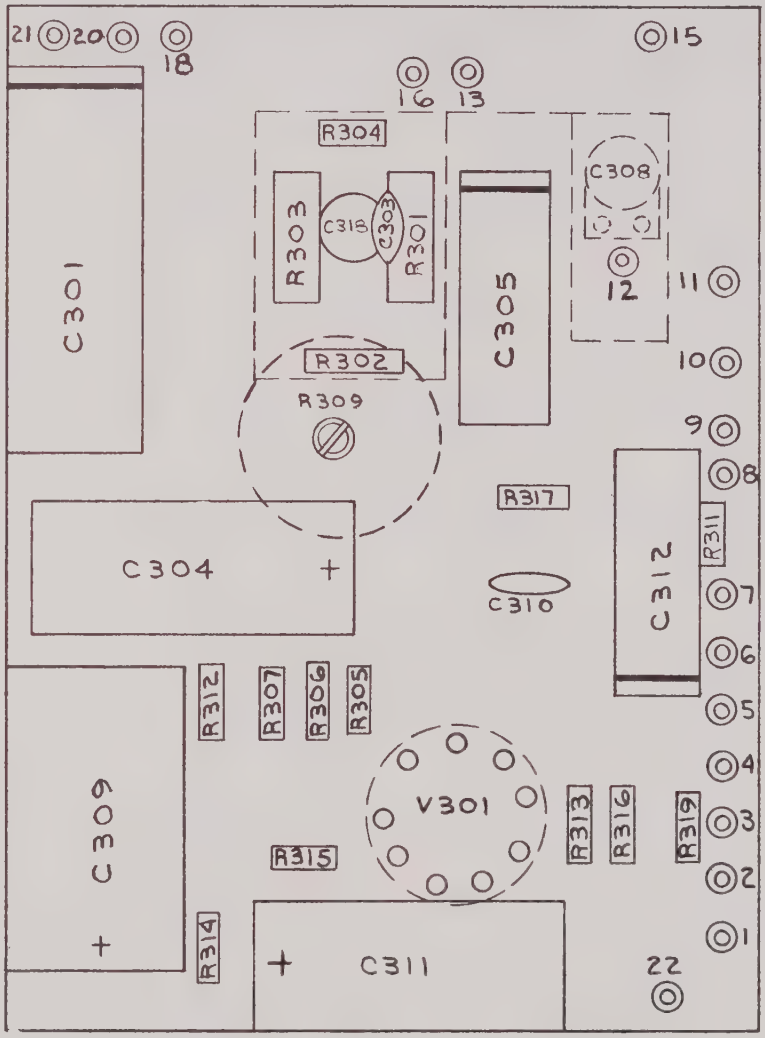

REF. PRE-AMPL. ASSY.
500086

Figure 4.3

(See Figure 3.4 for Schematic)

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REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	ASSEMBLY, Reference Amplifier (Fig. 4.4)	D500049	
C401	Capacitor, Fixed, 4ufd, 350V	800888	
C402	Capacitor, Fixed, 680uufd, 300V, ±5%	801787	
C403	Capacitor, Fixed, 200uufd, 500V, ±10%	802168	
C404	Capacitor, Fixed, .0022ufd, 200V, ±10%	802217	
C405,409 410,411	Capacitor, Fixed, .022ufd, 400V, ±10%	802235	
C406	Capacitor, Fixed, .022ufd, 200V, ±10%	802219	
C407,408	Capacitor, Fixed, .0047ufd, 200V, ±10%	802239	
C412	Capacitor, Fixed, 30ufd, 250V	801528	
CR401, 402	Diode, Silicon, IN658	801661	Clevite
R401,409,413, 416,427,431	Resistor, Fixed, Comp., 47Ω, 1/2W, ±10%	800991	
R402,410, 411	Resistor, Fixed, Comp., 68K, 1/2W, ±5%	800528	
R403	Resistor, Fixed, Comp., 82K, 1/2W, ±5%	801259	
R404,433	Resistor, Fixed, Comp., 1K, 1/2W, ±5%	800414	

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REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO	MANUFACTURER
	ASSEMBLY, Reference Amplifier (Fig. 4.4)	D500049	
R405	Resistor, Fixed, Comp., 47K, 1/2W, ±10%	800087	
R406	Resistor, Fixed, Comp., 3K, 1/2W, ±5%	800615	
R407	Resistor, Fixed, Comp., 390Ω, 1/2W, ±5%	800629	
R408	Resistor, Fixed, Comp., 430Ω, 1/2W, ±5%	800640	
R412	Resistor, Fixed, Comp., 10K, 1/2W, ±10%	800089	
R414,415	Resistor, Fixed, Comp., 10M, 1/2W, ±10%	801025	
R417,420, 424	Resistor, Fixed, Comp., 56K, 1/2W, ±5%	800857	
R418,419	Resistor, Fixed, Comp., 470Ω, 1/2W, ±10%	800084	
R421	Resistor, Fixed, Comp., 130K, 1/2W, ±5%	800806	
R422,423	Resistor, Fixed, Comp., 2.7K, 1/2W, ±5%	800643	
R425	Resistor, Fixed, Comp., 1.5M, 1/2W, ±10%	800378	
R426	Resistor, Fixed, Comp., 150K, 1/2W, ±10%	800057	

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200 terminal drive, plainview, n. y. OVerbrook 1-8600

REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	ASSEMBLY, Reference Amplifier (Fig. 4.4)	D500049	
R428,429	Resistor, Fixed, Comp., 2.2M, 1/2W, ±5%	800064	
R430	Resistor, Fixed, 30K, 2W, ±5%	802828	
R432	Resistor, Fixed, Comp., 200Ω, 1/2W, ±5%	801672	
V401,402,403	Tube, Electron 6U8A	800028	
S4	ASSEMBLY, Function Switch	500625	
R629	Resistor, Fixed, Dep. Carb., 93.7K, 1/2W, ±1%	801622	
R640	Resistor, Fixed, Dep. Carb., 937Ω, 1/4W, ±1%	801621	

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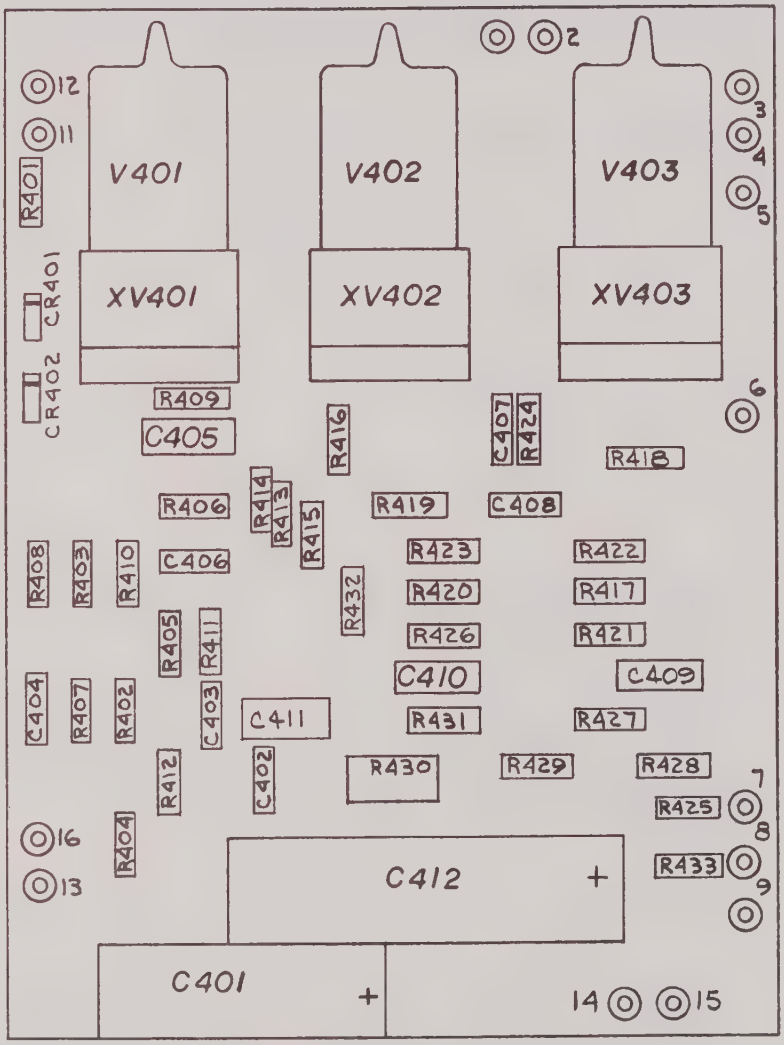

REF. AMPL. ASSY.
500049

Figure 4.4

NORTH ATLANTIC industries, inc.
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REPLACEMENT PARTS LIST

(continued)

(See Figures 3.11 thru 3.16 for Schematics)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
S6	ASSEMBLY, Frequency Switch	782400	
C645	Capacitor, Variable 8-50MMFD	800854	
R642	Resistor, Fixed, Comp., 100K, 1/2W, ±5%	800520	
	DECK #1 SUB-ASSEMBLY Figures 4.5 and 4.6	500607	
C603	Capacitor, Fixed, .143ufd,100V, ±1%	803619	Special
C604	Capacitor, Fixed, .0436 ufd, 100V, ±1%	803599	Special
C605	Capacitor, Fixed, .0138 ufd, 100V, ±1%	803600	Special
C606	Capacitor, Fixed, .00436ufd, 100V, ±1%	803601	
C607,C611	Capacitor, Fixed, 10ufd, 15V	801550	
C608	Capacitor, Fixed, 25uufd, 600V, ±5%	801543	
C609	Capacitor, Fixed, 2.24ufd, 50V, ±1%	803576	Special
C610	Capacitor, Fixed, 20ufd, 15V	801551	
C612	Capacitor, Fixed, 2ufd, 15V	801549	
C613	Capacitor, Fixed, 1ufd, 15V	801548	
C614	Capacitor, Fixed, .22ufd, 200V, ±10%	802233	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

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200 terminal drive, plainview, n. y. *OVerbrook 1-8600*

REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO	MANUFACTURER
S6	ASSEMBLY, Frequency Switch	782400	
	DECK #1 SUB-ASSEMBLY	500607	
C615	Capacitor, Fixed, .068ufd, 200V, ±10%	802225	
C616	Capacitor, Fixed, .022ufd, 200V, ±10%	802219	
C617	Capacitor, Fixed, .0068ufd, 200V, ±10%	802224	
R611	Resistor, Fixed, D.C., 60.5K, 1/4W, ±1/2%	802584	
R651, R654	Resistor, Fixed, Comp. 1.8K, 1/2W, ±5%	800858	
R652	Resistor, Fixed, Comp. 4.3K, 1/2W, ±5%	800621	
R653	Resistor, Fixed, Comp. 430K, 1/2W, ±5%	802470	
R655	Resistor, Fixed, Comp. 750Ω, 1/2W, ±5%	800911	
R656, R657	Resistor, Fixed, Comp. (Select at Test)		
	DECK #2 SUB-ASSEMBLY	500608	
C624A-C631A	Capacitor, Fixed (Select at Test)		
C618,C621	Capacitor, Fixed, .709ufd, 100V, ±1%	803587	Special

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

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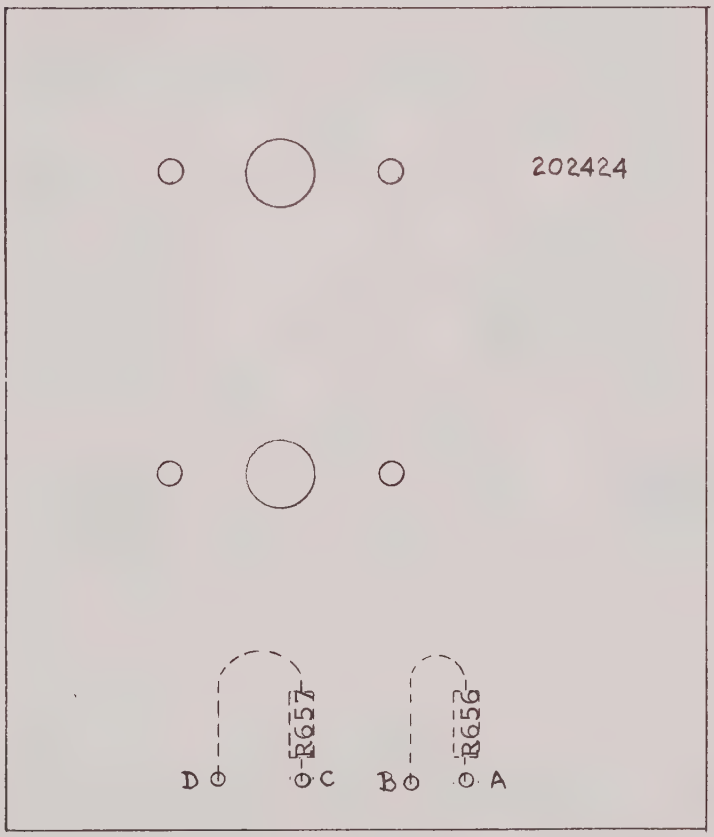
NOTE: Dash line components are select at test.
See Figure Figure 3.12 and Alignment Procedure
of Section V.



REAR
DECK #1

FIGURE 4.5
(See Figure 3.12 for Schematic)

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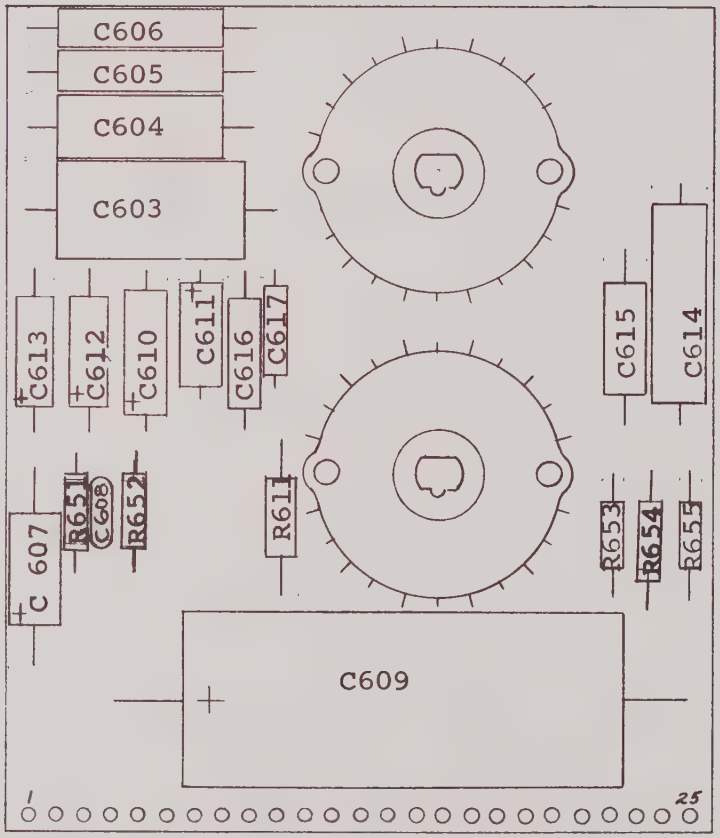

FRONT
FREQUENCY SWITCH
DECK #1

FIGURE 4.6

(See Figure 3.12 for Schematic)

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REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	DECK #2 SUB-ASSEMBLY Figures 4.7 & 4.8	500608	
C619,C622	Capacitor, Fixed, .224 ufd, 100V, ±1%	803588	Special
C620,C623	Capacitor, Fixed, .0709ufd, 100V, ±1%	803589	Special
C624	Capacitor, Fixed, 1.9ufd,100V, ±2%	803590	Special
C625	Capacitor, Fixed, .6ufd,100V, ±2%	803591	Special
C626	Capacitor, Fixed, .19ufd, 100V,±2%	803592	Special
C627	Capacitor, Fixed, .06ufd, 100V, ±2%	803593	Special
C628	Capacitor, Fixed, .38ufd, 100V, ±2%	803594	Special
C629	Capacitor, Fixed, .12ufd, 100V, ±2%	803595	Special
C630	Capacitor, Fixed, .038ufd, 100V, ±2%	803596	Special
C631	Capacitor, Fixed, .012ufd, 100V, ±2%	803597	Special
R617A,R616A	Resistor, Fixed(Select at Test)		
R613	Resistor, Fixed, D.C., 3.95K 1/4W, ±1/2%	801705	
R614	Resistor, Fixed, D.C., 39.5Ω, 1/4W, ±1/2%	801692	

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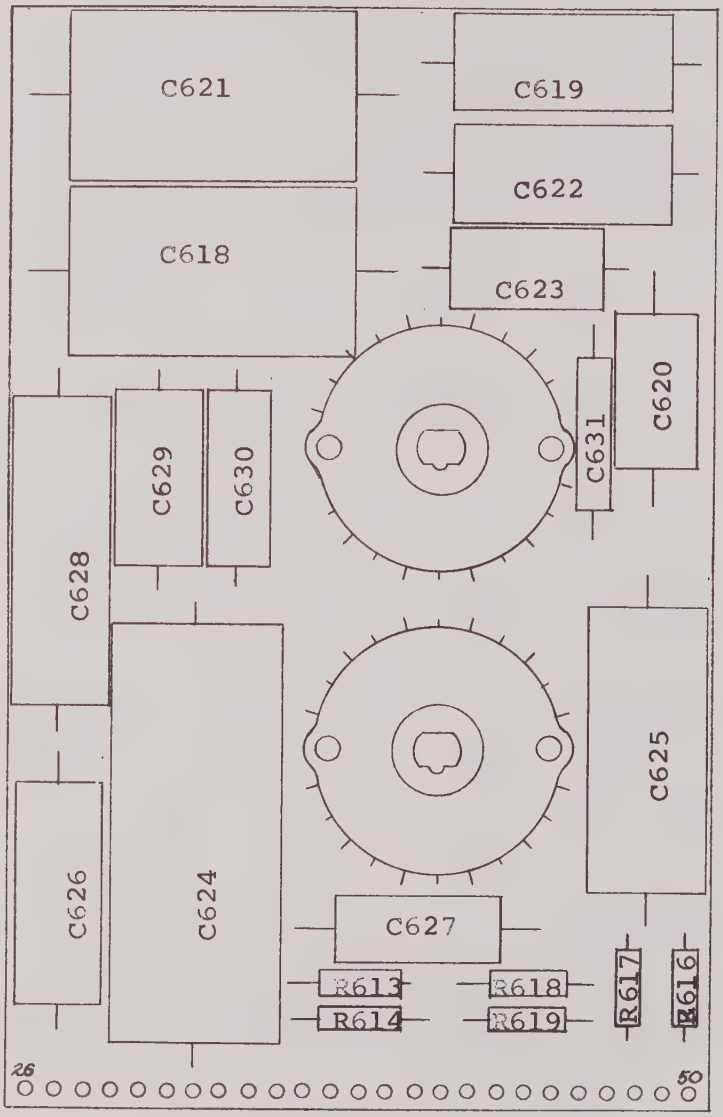

FRONT
FREQUENCY SWITCH
DECK #2

Figure 4.7
(See Figure 3.13 for Schematic)

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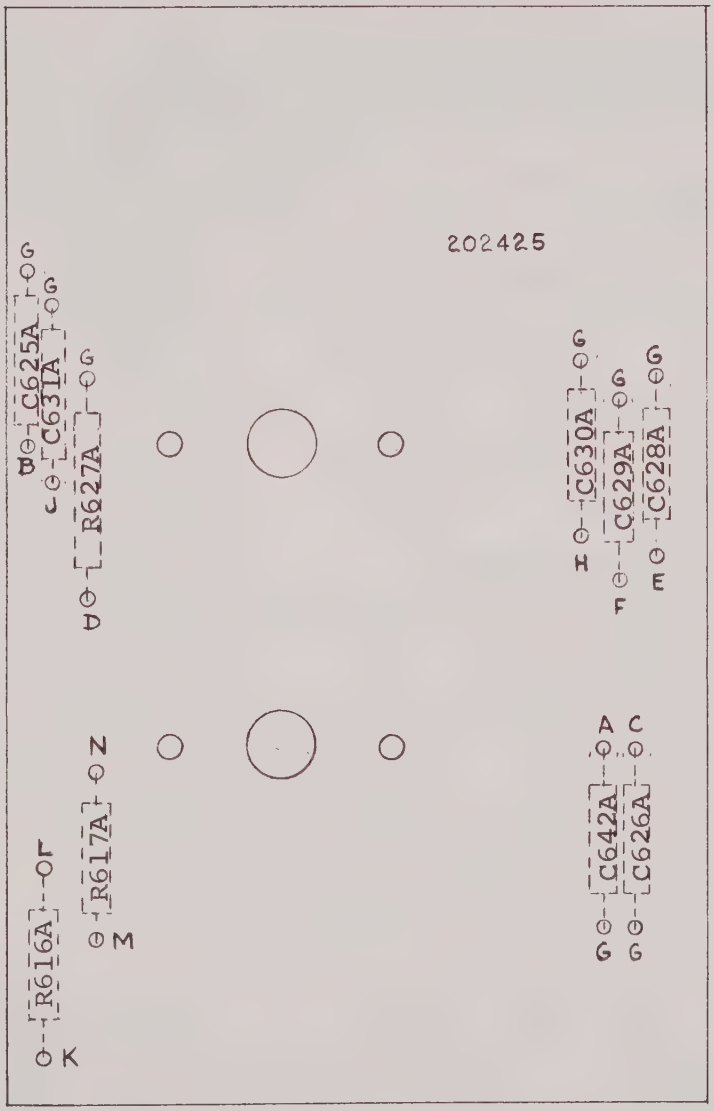
200 terminal drive, plainview, n. y. OVerbrook 1-8600

NOTE: Dash line components are select at test. See Figure 3.13 and Alignment Procedure, Paragraph XIII.



REAR
FREQUENCY SWITCH
DECK #2

Figure 4.8

(See Figure 3.13 for Schematic)

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	DECK #2 SUB-ASSEMBLY	500608	
R616	Resistor, Fixed, D.C., 23.5K, 1/4W, ±1/2%	801707	
R617	Resistor, Fixed, D.C., 235Ω, 1/4W, ±1/2%	801697	
R618	Resistor, Fixed, D.C., 4.7K, 1/4W, ±1/2%	801706	
R619	Resistor, Fixed, D.C., 47Ω, 1/4W, ±1/2%	801694	
	DECK #3 SUB-ASSEMBLY Figures 4.9 & 4.10	500609	
C632	Capacitor, Fixed, .143ufd, 100V, ±1%	803619	Special
C633	Capacitor, Fixed, .0436ufd, 100V, ±1%	803599	Special
C634	Capacitor, Fixed, .0138ufd, 100V, ±1%	803600	Special
C635	Capacitor, Fixed, .00436ufd, 100V, ±1%	803601	Special
C636	Capacitor, Fixed, .204ufd, 100V, ±1%	803602	Special
C637	Capacitor, Fixed, .0642ufd, 100V, ±1%	803603	Special
C638	Capacitor, Fixed, .0204ufd, 100V, ±1%	803604	Special
C639	Capacitor, Fixed, .00642ufd, 100V, ±1%	803605	Special

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*

200 terminal drive, plainview, n. y. *OVerbrook 1-8600*

REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	DECK #3 SUB-ASSEMBLY Figures 4.9 & 4.10	500609	
C640	Capacitor, Fixed, .19ufd, 100V, ±2%	803592	Special
C641	Capacitor, Fixed, .06ufd, 100V, ±2%	803593	Special
C642	Capacitor, Fixed, .019ufd, 100V, ±2%	803606	Special
C643	Capacitor, Fixed, .006ufd, 100V, ±2%	803607	Special
C644	Capacitor, Fixed, 2.24ufd, 50V, ±1%	803576	Special
R604	Resistor, Fixed, DC, 66.5K, 1/4W, ±1%	801710	
R605	Resistor, Fixed, Comp., Select At Test		
R606	Resistor, Fixed, D.C., 583Ω, 1/4W, ±1/2%	802585	
R609	Resistor, Fixed, D.C., 665Ω, 1/4W, ±1%	801702	
R612	Resistor, Fixed, D.C., 438Ω, 1/4W, ±1/2%	801698	
R615	Resistor, Fixed, D.C., 43.8K, 1/4W, ±1/2%	801708	
R634	Resistor, Fixed, D.C., 3.95K, 1/4W, ±1%	800820	

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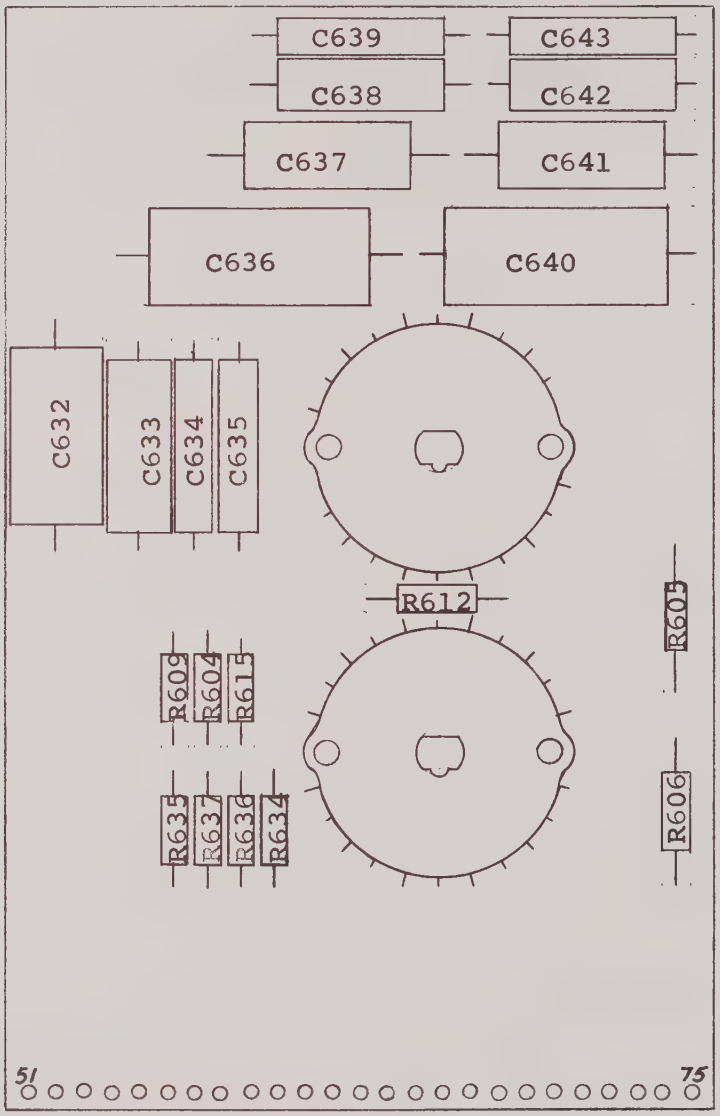
11/7/66
11/17/69

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600



FRONT
FREQUENCY SWITCH
DECK #3

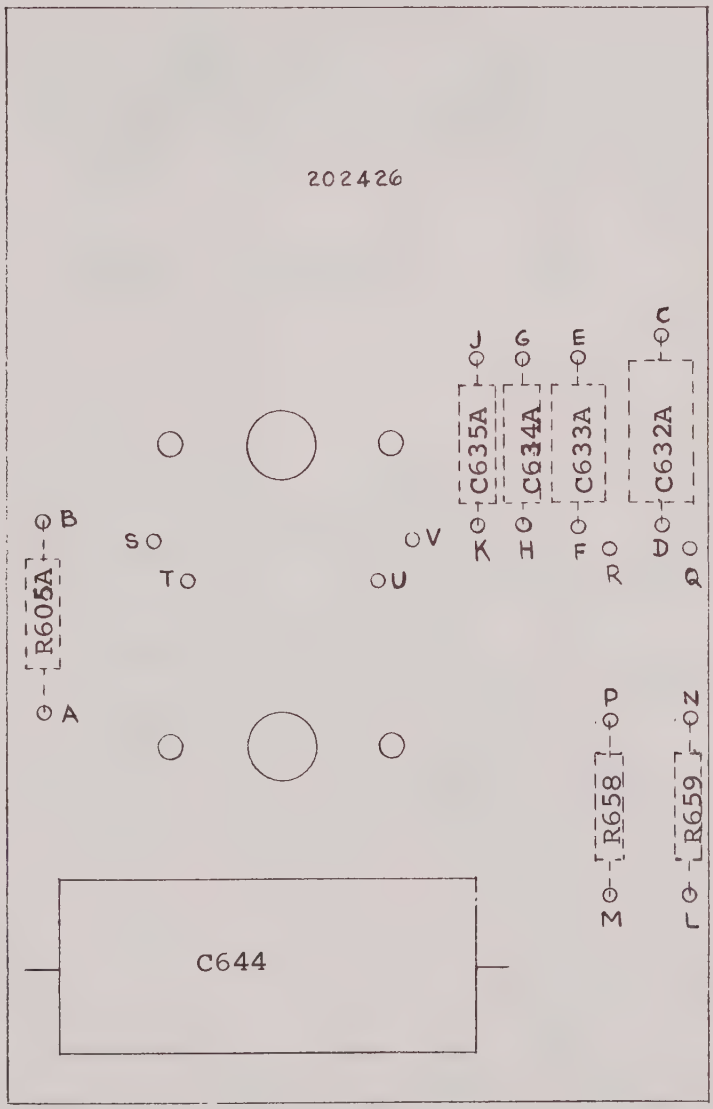
Figure 4.9

(See Figure 3.14 for Schematic)

5/4/70

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

Dash line components are select at test.
NOTE: See Figure 3.14 and Alignment Procedure, Paragraph XIII.



REAR
FREQUENCY SWITCH
DECK #3

Figure 4.10

(See Figure 3.14 for Schematic)

5/4/70

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	DECK #3 SUB-ASSEMBLY	500609	
R635	Resistor, Fixed, D.C., 39.5Ω, 1/4W, ±1%	801693	
R636	Resistor, Fixed, D.C., 150K, 1/4W, ±1%	802451	
R637	Resistor, Fixed, D.C., 1.48K, 1/4W, ±1/2%	803612	
TB6	ASSEMBLY, TERMINAL BOARD Figure 4.11	500292	
C601, 602	Capacitor, Fixed, .0033ufd, 200V, ±10%	802221	
R601, 602	Resistor, Fixed, Comp., 680Ω, 1/2W, ±5%	800638	
R610, 624	Resistor, Fixed, Dep. Carb., 287.5Ω, 1/4W, ± 1/4%	806357	
R620, 623	Resistor, Fixed, Dep. Carb., 2.25K, 1/4W, ±1/4%	801704	
R621, 622	Resistor, Fixed, Dep. Carb., 158Ω, 1/4W, ±1/4%	802763	
R625, 626	Resistor, Fixed, Dep., Carb., 14.25Ω, 1/4W, ± 1/4%	806358	
R627	Resistor, Fixed, Dep. Carb., 27Ω, 1/4W, ±1%	806362	
R631	Resistor, Fixed, Dep. Carb., 166Ω, 1/4W, ±1%	802764	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

REPLACEMENT PARTS LIST

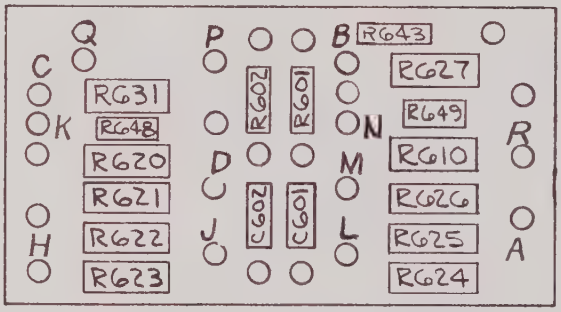
(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
TB6	ASSEMBLY, TERMINAL BOARD	500292	
R643	Resistor, Comp., 200Ω, 1/2W, ±5%	801672	
R648, 649	Resistor, Comp., 1/2W, (Select at Test)		
TB6A	TERMINAL BOARD Figure 4.12 This Terminal Board is added to all instruments after S/N #8251. It will contain all components selected at test which were formerly contained on the Frequency Switch Assembly. The function of these components is identical to their previous function. (See Schematics, Figures 3.12, 3.13, 3.14, 3.15, 3.16)		

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

11/7/66
5/4/70

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600



TERM. BOARD ASSY. (TB6)
500292

Figure 4.11

(See Figures 3.11 thru 3.16 for Schematic)

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200 terminal drive, plainview, n. y. overbrook 1-8600

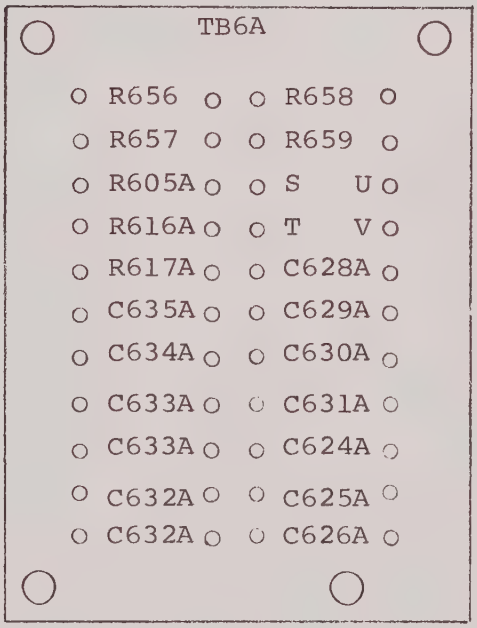


Figure 4.12

(See Figure 3.11 thru 3.16 for Schematic)

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	ASSEMBLY, MONITOR VOLTMETER TERMINAL BOARD (Fig. 4.13)	500048	
C701	Capacitor, Fixed, 20ufd, 250V	801221	
C702	Capacitor, Fixed, .022ufd,200V	802219	
C703	Capacitor, Fixed, 100ufd, 6V	800600	
C704, 706	Capacitor, Fixed, .47ufd, 400V	800866	
C705	Capacitor, Fixed, 47ufd, 6V	801010	
C707	Capacitor, Fixed, .1ufd, 200V	802220	
CR701, 703	Diode, IN82A	800867	
CR702	Diode, IN461	800942	Clevite
R701, 710	Resistor, Fixed, Comp., 47Ω, 1/2W, ±10%	800991	
R702	Resistor, Fixed, Comp., 220Ω, 1/2W, ±10%	802301	
R703	Resistor, Fixed, Comp., 82K, 1/2W, ±5%	801259	
R704	Resistor, Fixed, Comp., 22K, 1/2W, ±10%	800155	
R705	Resistor, Fixed, Comp., 27K, 1/2W, ±10%	800088	
R706	Resistor, Fixed, Comp., 180K, 1/2W, ±5%	801260	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

11/7/66
11/11/69

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

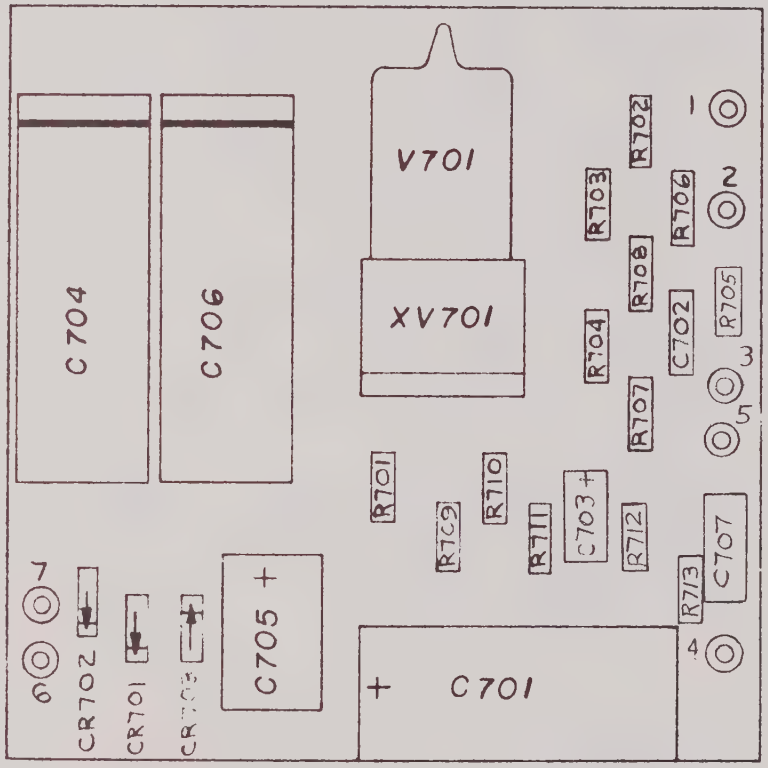
REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	ASSEMBLY, MONITOR VOLTMETER TERMINAL BOARD (Fig. 4.13)	500048	
R707	Resistor, Fixed, Comp., 560Ω, 1/2W, ±5%	801258	
R708	Resistor, Fixed, Comp., 47Ω, 1/2W, ±5%	800855	
R709	Resistor, Fixed, Comp., 2.2M, 1/2W, ±5%	800064	
R711	Resistor, Fixed, Comp., 47K, 1/2W, ±10%	800087	
R712	Resistor, Fixed, Comp., 680Ω, 1/2W, ±5%	800638	
R713	Resistor, Fixed, Comp, 2Meg., 1/2W, ±5%	802173	
V701	Tube, Electron, 6U8A	800028	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600



MONITOR VOLTMETER TERMINAL BOARD ASSY.
500048

Figure 4.13

(See Figure 3.7 for Schematic)

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. overbrook 1-8600

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Reference Drive Amplifier Figure 4.14	500050	
C801,805, 806, 822	Capacitor, Fixed, .1ufd, 200V, ±10%	802220	
C802	Capacitor, Fixed, .0022ufd, 400V, ±10%	802240	
C803	Capacitor, Fixed, .01ufd, 200V, ±10%	801879	
C804	Capacitor, Fixed, 30ufd, 250V	802774	
C807	Capacitor, Variable, 5-25 uuf	801483	
C808	Capacitor, Fixed, .0047ufd, 200V, ±10%	802239	
C809, 812	Capacitor, Fixed, .0018ufd, 400V, ±10%	802236	
C810, 811	Capacitor, Fixed, .0047ufd, 400V, ±5%	802281	
C813, 815	Capacitor, Fixed, .022ufd, 200V, ±10%	802219	
C814	Capacitor, Fixed, 100uufd, 500V, ±5%	801264	
C816, 817	Capacitor, Fixed, 0.1uf, 200V, ±10%	802220	
C818, 819	Capacitor, Fixed, 4ufd, 200V, ±5%	802245	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

REPLACEMENT PARTS LIST

(continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Reference Drive Amplifier Figure 4.14	500050	
C820, 821	Capacitor, Fixed, .022uf, 400V	802235	
C823	Capacitor, Fixed, .22uf, 100V	802863	
C824	Capacitor, Fixed, 27uuf, 500V	801925	
R801	Resistor, Fixed, Comp., 2.2M, 1/2W, ±5%	800064	
R802,805,811, 814,822,823, '832,837	Resistor, Fixed, Comp., 47Ω, 1/2W, ±10%	800991	
R803,810,824	Resistor, Fixed, Comp., 100K 1/2W, ±10%	800086	
R804	Resistor, Fixed, Comp., 4.3K 1/2W, ±5%	800621	
R806	Resistor, Fixed, Comp., 5.6K, 1/2W, ±5%	800641	
R807	Resistor, Fixed, Dep. Carb., 10.4K, 1/4W, ±1%	802840	
R808	Resistor, Fixed, Comp., 1K, 1/2W, ±5%	800414	
R809	Resistor, Fixed, Dep. Carb., 9K, 1/4W, ±1%	802717	
R812	Resistor, Fixed, Comp., 240K, 1/2W, ±5%	801282	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Reference Drive Amplifier Figure 4.14	500050	
R815,825	Resistor, Fixed, Comp., 68K, 1/2W, ±5%	800528	
R816,821	Resistor, Fixed, Comp., 6.2K, 1/2W, ±5%	800614	
R826,829,830, 831	Resistor, Fixed, Comp., 110K, 1/2W, ±5%	800682	
R817,820	Resistor, Fixed, Comp., 8.2K, 1/2W, ±5%	800626	
R818,819	Resistor, Fixed, Comp., 22M, 1/2W, ±10%	801754	
R827, 828	Resistor, Fixed, Comp., 470Ω, 1/2W, ±10%	800084	
R833,836	Resistor, Fixed, Comp., 10M, 1/2W, ±10%	801025	
R834,835	Resistor, Fixed, Comp., 68Ω, 1/2W, ±5%	801139	
R838,847,850	Resistor, Fixed, Dep. Carb., 40Ω, 1/4W, ±1%	802862	
R839,842	Resistor, Fixed, Comp., 24K, 2W, ±5%	802246	
R840,841	Resistor, Fixed, Dep. Carb., 5.6K, 1/4W, ±1%	802247	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*

200 terminal drive, plainview, n. y. *OVerbrook 1-8600*

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Reference Drive Amplifier Figure 4.14	500050	
R843,844	Resistor, Fixed, Dep. Carb., 1.5K, 1/4W, ±1%	802248	
R845,846	Resistor, Fixed, Comp., 56K, 1/2W, ±5%	800857	
R848,849	Resistor, Fixed, Dep. Carb., 910Ω, 1/4W, ±1%	802249	
R851,852	Resistor, Fixed, Dep. Carb., 10M, 1W, ±1%	802253	
R853	Resistor, Fixed, Comp., 22K, 1/2W, ±10%	800155	
R854	Resistor, Fixed, Comp., 200K, 1/2W, ±5%	801873	
R855	Resistor, Fixed, W.W. 0.56Ω, 2W, ±10%	802399	
R856,813	Resistor, Select at Test, Nominally 2.4 Meg.		
V801,802	Tube, Electron, 6U8A	800028	
V803,V804	Tube, Electron, 6AN8	801521	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

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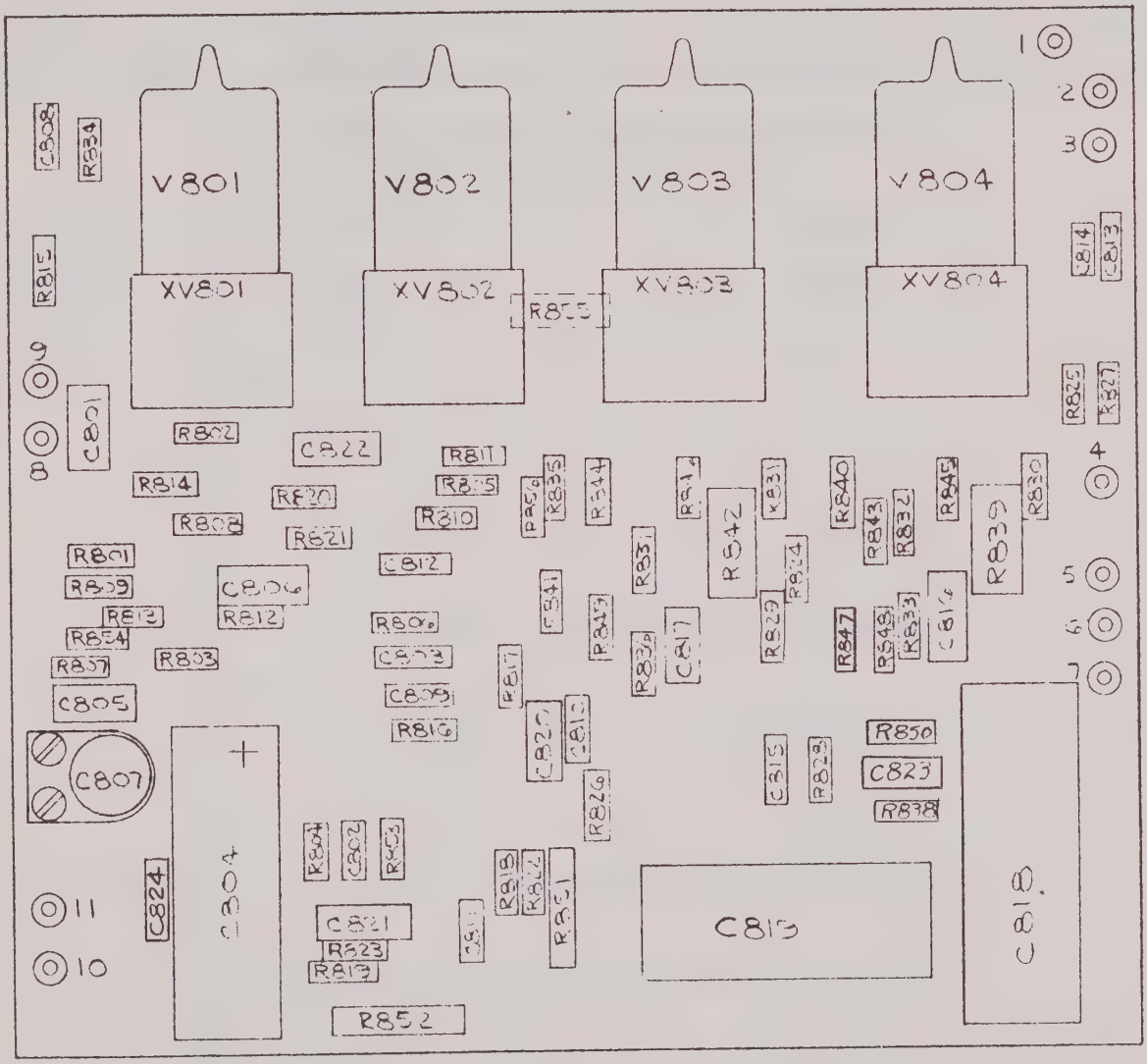

REFERENCE DRIVE AMPLIFIER ASSEMBLY

500050

Figure 4.14

(See Figure 3.8 for Schematic)

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Power Supply Board Figure 4.15	500083	
*C901	Capacitor, Fixed, 20ufd, 350V	800847	* Used as input cap. with silicon rectifier.
*C902	Capacitor, Fixed, 30ufd, 250V	801528	
*C903,904 909	Capacitor, Fixed, 20ufd, 250V	801221	
C905	Capacitor, Fixed, .0022 ufd, 400V, ±10%	802240	
C906	Capacitor, Fixed, .01ufd, 200V, ±10%	801879	
C907	Capacitor, Fixed, 24uufd, 500V, ±5%	802216	
C908	Capacitor, Fixed, .33ufd, 200V, ±10%	801527	
C910	Capacitor, Fixed, 20ufd, 450V	801222	
C911	Capacitor, Fixed, 100ufd, 500V, ±10%	801264	
C913	Capacitor, Fixed, .001ufd, 200V, ±10%	802218	
C914	Capacitor, Fixed, 150uufd, 500V, ±5%	801365	
C915	Capacitor, Fixed, 4ufd, 350V	800888	
C916	Capacitor, Fixed, 10ufd, 50V	802209	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *OVerbrook 1-8600*

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Power Supply Board Figure 4.15	500083	
CR901,902	Diode, SR200B	803735	Sylvania
CR903,904	Diode, IN2071	800986	
CR905,906	Diode, IN1692	800987	G.E.
CR907*	Diode, Zener 1N979B	803114	
DS902	Lamp, Neon, NE76	801523	
Q901	Transistor, TR650	801522	
Q902	Transistor, 2N398	801520	
Q903	Transistor, 2N1539	802441	
Q904,905	Transistor, 2N1381	800872	
Q906	Transistor, 2N697	803809	
R901,902,910, 916	Resistor, Fixed, Comp., 22Ω, 1/2W, ±10%	800988	
R903,R904	Resistor, Fixed, WW, 2.5K, 3W, ±5%	802374	
R905	Resistor, Fixed, Metal Film, 160K, 1/2W, ±1%	802347	
R906	Resistor, Fixed, Metal Film, 82K, 1/2W, ±1%	802348	
*922,929	Resistor, Fixed, Comp., 220K, 1/2W, ±10%	800058	*See page 4.48

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

11/7/66
11/17/69
5/4/70

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Power Supply Board Figure 4.15	500083	
R908**	Resistor, Fixed, Comp., 27K, 1/2W, ±10%	800088	
R909	Resistor, Fixed, Comp., 430Ω 1/2W, ±5%	800640	
R911	Resistor, Fixed, Comp., 160K, 1/2W, ±5%	800859	
R912**	Resistor, Fixed, Comp., 33K, 1/2W, ±10%	800839	
R913	Resistor, Fixed, Comp., 100K, 1/2W, ±10%	800086	
R914	Resistor, Fixed, Comp., 470K, 1/2W, ±10%	800060	
R915	Resistor, Fixed, Comp., 2.7Ω, 1W, ±10%	801738	
R917	Resistor, Fixed, WW, 25Ω, 3W, ±5%	800075	
R918	Resistor, Fixed, WW, 5K, 7W, ±10%	802463	
R919	Resistor, Fixed, Metal Film, 35K, 1/4W, ±1%	802543	
R920	Resistor, Fixed, Comp., 36K, 1/2W, ±5%	801016	

** Nominal value - trimmed at test.

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Power Supply Board Figure 4.15	500083	
R921	Resistor, Fixed, Comp., 47Ω,	800991	
R923	Resistor, Fixed, Metal Film, 218K, 1/2W, ±1%	802210	
R924	Resistor, Fixed, Metal Film, 14K, 1/2W, ±1%	802439	
R925	Resistor, Fixed, Comp., 4.7K, 1/2W, ±10%	800078	
R926	Resistor, Fixed, Comp., 68K, 1/2W, ±5%	800528	
R927	Resistor, Fixed, Comp., 150Ω, 1/2W, ±5%	801140	
R928	Resistor, Fixed, Comp., 12K, 1/2W, ±5%	800644	
R930**	Resistor, Fixed, Comp., 39K, 1/2W, ±10%	801069	
R932	Resistor, Fixed, Comp., 30K, 1/2W, ±5%	800622	
R933	Resistor, Fixed, Comp., 1.5M, 1/2W, ±5%	802214	
R934	Resistor, Fixed, Comp., 150K, 1/2W, ±5%	800856	

** Nominal value - trimmed at test.

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *OVerbrook 1-8600*

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Power Supply Board Figure 4.15	500083	
R935	Resistor, Fixed, Comp., 270K, 1/2W, ±5%	802213	
R936	Resistor, Fixed, Comp., 110Ω, 1/2W, ±5%	801145	
R937**	Resistor, Fixed, Comp., 240K, 1/2W, ±5%	801282	
R938**	Resistor, Fixed, Comp., 1.8K, 1/2W, ±5%	800858	
V901	Tube, Electron, 6AN8	801521	
V902	Tube, Electron, 12B4A	800973	

CR907 (1N979B) replaces DS902 (NE76) and R907 is changed to 150K (same as R934) in all instruments after serial #13700

** Nominal value - trimmed at test.

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

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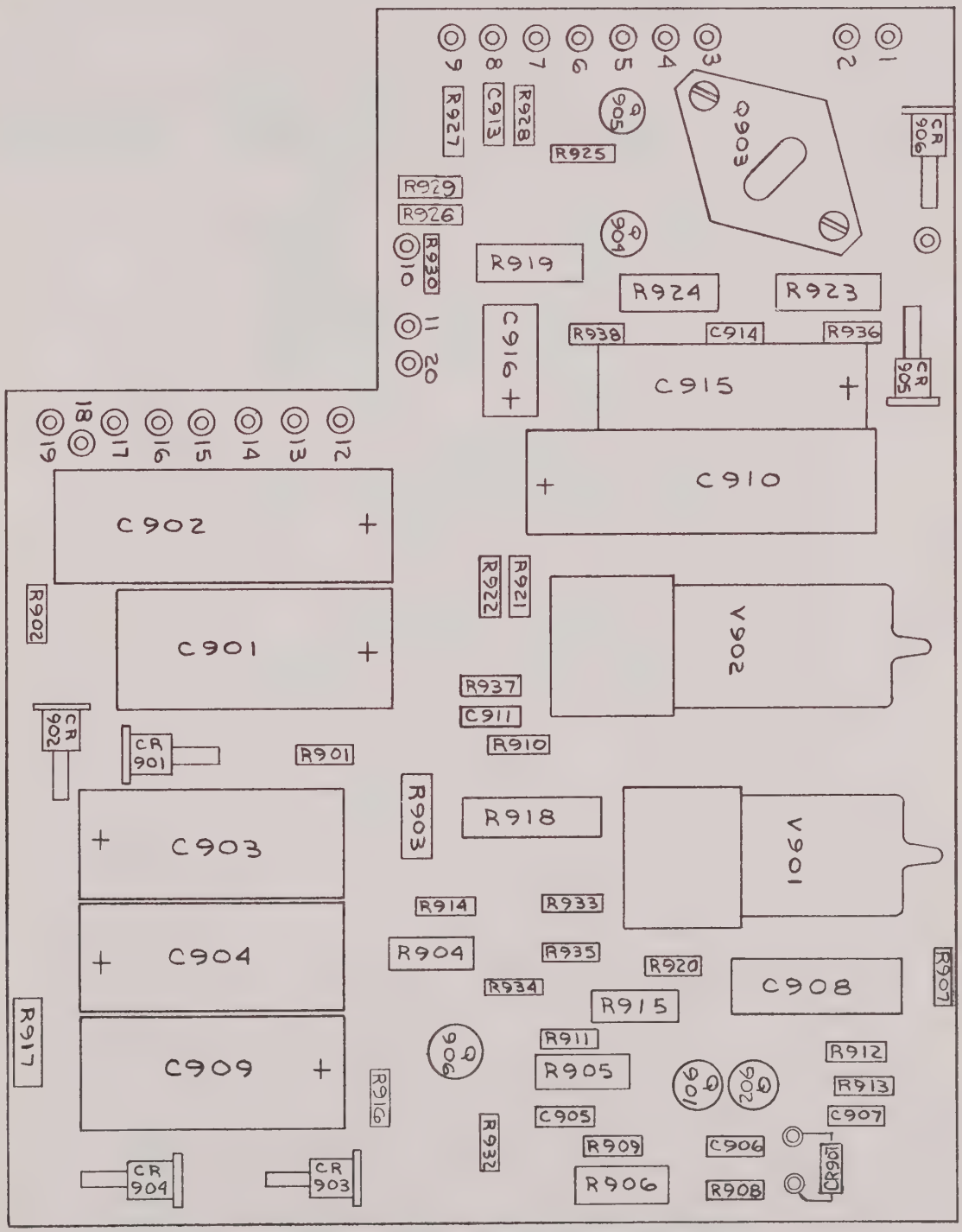

POWER SUPPLY TERMINAL BOARD ASSY.
500083

Figure 4.15
4.49
(See Figure 3.10 for Schematic)

5/4/70
S16

REPLACEMENT PARTS LIST

DESIGNATION	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Meter Board Figure 4.16	500181	
C1001,C1002	Capacitor, Fixed, 47uf, 6V	801010	
C1003	Capacitor, Fixed, .047uf, 400 400V	802395	
CR1001,1002	Diode, 1N461	800942	Clevite
R1001	Resistor, Fixed, Comp., 10Ω, 1/2W, ±10%	801518	
R1002	Resistor, Fixed, Comp., 3K, 1/2W, ±5%	800615	
R1003	Resistor, Fixed, Comp., 22 Meg, 1/2W, ±10%	802395	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

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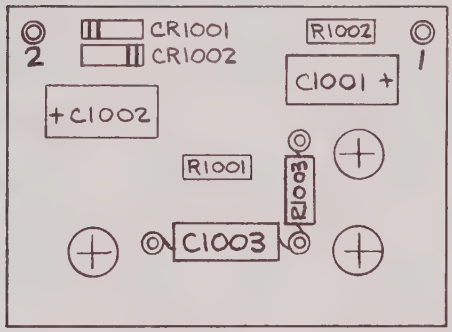

METERBOARD ASSEMBLY

500181

Figure 4.16

(See Figure 3.3 for Schematic)

REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Signal Decoupling Board Figure 4.17	500177	
C1102	Capacitor, Fixed, 4ufd, 350V	800888	
C1103	Capacitor, Fixed, 50ufd, 250V	801737	
DS1101	Lamp, Neon, NE76	801523	
R1101	Resistor, Fixed, Comp., 220K, 1/2W, ±5%	800977	
R1102	Resistor, Fixed, Comp., 56K, 1/2W, ±5%	800857	
R1103	Resistor, Fixed, Comp., 20K, 1/2W, ±5%	800521	

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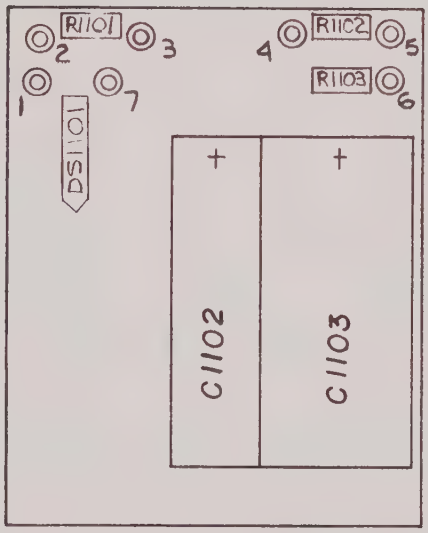

SIG. DE-COUPLING BOARD ASSY.
500177

Figure 4.17

(See Figure 3.10 for Schematic)

5/4/70

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REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Signal Filter and Overload Figure 4.18	500276	
C1201,1202	Capacitor, Fixed, .22ufd, 400V, ±20%	800021	
C1203,1205	Capacitor, Fixed, .1ufd, 400V, ±20%	800020	
C1204	Capacitor, Fixed, 40uf at 75V	800507	
R1201	Resistor, Fixed, Comp., 270K, 1/2W, ±5%	800059	
R1202	Resistor, Fixed, Comp., 130K, 1/2W, ±5%	800806	
R1203	Resistor, Fixed, Comp., 2.2K, 1/2W, ±5%	800079	
R1204	Resistor, Fixed, Dep. Carb., 11K, 1/2W, ±1%	801662	
R1205	Resistor, Fixed, Comp., 10M, 1/2W, ±10%	801025	

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11/7/66
5/4/70

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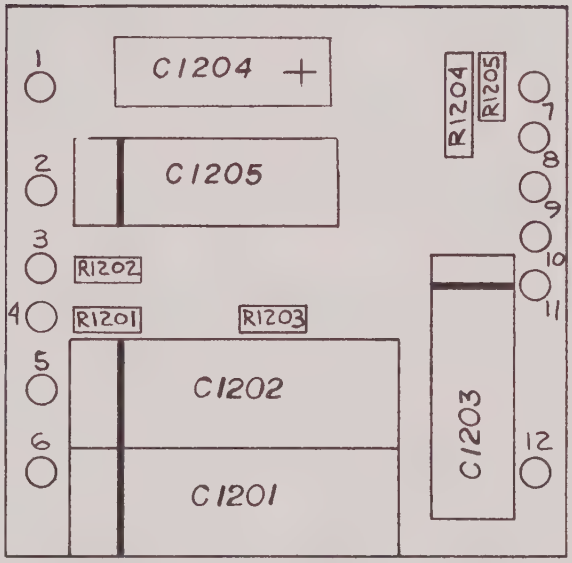

SIGNAL FILTER & OVERLOAD ASSY.
500276

Figure 4.18

(See Figure 3.3 for Schematic)

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REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Range Switch	782401	
	Sub-Assembly Deck #1	500615	
C1301	Capacitor, Variable, 3-12uufd	801512	
C1303	Capacitor, Fixed, .1ufd, 600V	802789	
C1304	Capacitor, Fixed, .027ufd, 100V, ±5%, Polystyrene	802571	
C1305	Capacitor, Fixed, 3.9uufd, 500V, ±5%	802163	
C1317	Capacitor, Fixed, 22uufd, ±5%	802572	
C1318	Capacitor, Fixed, .22ufd, 200V	802790	
R1301	Resistor, Fixed, Metal Film, 10M, 1/2W, ±1/2%	802516	
R1302	Resistor, Fixed, Metal Film, 10K, 1/2W, ±1/4%	802517	
R1303	Resistor, Fixed, Comp., 12K, 1/2W, ±5%	800644	
R1304	Resistor, Fixed, Comp., 120Ω, 1/2W, ±5%	800407	
R1305,1319	Resistor, Fixed, Comp., 20M, 1/2W, ±5%	801482	
R1318	Resistor, Fixed, W.W., .75Ω, 2W, ±5%	802583	

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REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Range Switch	782401	
	Sub-Assembly Deck #2	500616	
C1302	Capacitor, Variable, 6-25uufd	802793	
C1306	Capacitor, Fixed, 43uufd, 500V ±2%	802446	
C1307	Capacitor, Fixed, 150uufd, 500V, ±2%	802447	
C1308	Capacitor, Fixed, 220uufd, 500V, ±5%	802448	
C1309	Capacitor, Fixed, 250uufd, 500V, ±5%	802449	
C1310	Capacitor, Fixed, 300uufd, 300V, ±5%	802450	
C1311, 1312,1313, 1314,1315,1316	Capacitor, Fixed, .1ufd, 200V, ±10%	802220	
CR1301,1302	Diode, 1N483	803989	
R1306	Resistor, Fixed, Metal Film, 6.84K, 1/8W, ±1/4%	801474	
R1307	Resistor, Fixed, Metal Film, 2.16K, 1/8W, ±1/4%	801475	
R1308	Resistor, Fixed, Metal Film, 684Ω, 1/8W, ±1/4%	801476	

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11/7/66
11/11/69

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REPLACEMENT PARTS LIST

(Continued)

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Assembly, Range Switch	782401	
	Sub-Assembly Deck #2	500616	
R1309	Resistor, Fixed, Metal Film, 216Ω, 1/8W, ±1/4%	801477	
R1310	Resistor, Fixed, Metal Film, 68.4Ω, 1/8W, ±1/4%	801478	
R1311	Resistor, Fixed, Metal Film, 31.6Ω, 1/8W, ±1/4%	801479	
R1312,1313, 1314,1315, 1316,1317	Resistor, Fixed, Comp., 20M, 1/2W, ±5%	801482	

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REPLACEMENT PARTS LIST

LOOSE COMPONENTS

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
R1003	Potentiometer, 50K, 2W	800056	
XF1	Fuseholder	800137	
F1	Fuse, 2 Amp., 3AG	800935	
	Link, Shorting	800339	
	Binding Post (Red)	800119	
	Binding Post (Black)	800120	
	Binding Post (Ground)	800546	
M701	Meter, Ref. Level	B800565	
B1	Motor	803665	
	Fan	803666	
	Knob, Small Round	B201720	
	Knob, Small Round (with white indicator line)	B201720-1	

Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

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REPLACEMENT PARTS LIST

LOOSE COMPONENTS

CIRCUIT REF	DESCRIPTION	NAI PART NO	MANUFACTURER
	Knob, Medium Pointer	B-201719-1	
	Knob, Large Round	B-201724	
	Knob (Freq. Switch)	A-202796	
	Cord, Std. Thin Nylon	900642	Gen. Cement #75
	Spring, Dial Drive	803614	Walsco #7407-F
DS1201	Lamp, Overload	A-202778	
XDS1201	Connector, Cartridge	802951	Dialco #7538-XP12
	Clip, Speed	802952	Dialco #7538-XP51
DS3,DS4	Lamp, Midget Screw Base #1768	802767	
DS5,DS6	Lamp, Meter #51	803611	
XDS3,XDS4	Lampholder, Midget Screw Base	802768	Dialco #16-08
	Meter & Filter Door Assembly	500624	
R105	Potentiometer, 5K, 1/2W	801472	
R108	Resistor, Fixed, D.C., 5K, 1/2W, ±1%	801166	
R318	Resistor, Fixed, D.C., 10K, 1/2W, ±1%	801481	
M1001	Meter	202556	

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11/7/66
11/11/69

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200 terminal drive, plainview, n. y. OVerbrook 1-8600

REPLACEMENT PARTS LIST

LOOSE COMPONENTS

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
	Phase Dial Assembly	500619	
T601	Driver Transformer (LF)	200612	
T602	Driver Transformer (HF)	200611	
T901	Power Transformer	200688	
R242	Potentiometer, 250Ω, 1/2W	801471	
R321	Potentiometer. Ref. Level	202788	
R505	Potentiometer, 1.5K, 2W (Zero)	803621	
R633	Potentiometer, 100Ω (Equal)	803622	
R644	Potentiometer (Phase)	802811-1	
R320	Resistor, Fixed, Comp., 12K, 1/2W, ±5%	800644	
R322	Resistor, Fixed, Comp., 56Ω, 1/2W, ±5%	801653	
R603	Resistor, Fixed, Comp., Select at Test		
R628,R630	Resistor, Fixed, DC, 90.6K, 1/2W, ±1/4%	802786	
R638,R641	Resistor, Fixed, DC, 906Ω, 1/2W, ±1/4%	802785	
R632	Resistor, Fixed, Comp., 2.2M, 1/2W, ±5%	800064	
R639	Resistor, Fixed, Comp., 1K, 1/2W, ±10%	800166	

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REPLACEMENT PARTS LIST

CIRCUIT REF	DESCRIPTION	NAI PART NO.	MANUFACTURER
R939	Resistor, Fixed, Comp., 4.7Ω, 1W	803869	
C313	Capacitor, Fixed, 3.9uuf, 500V, ±5%	802163	
C314	Capacitor, Fixed, 220uuf, 500V, ±5%	802448	
C315	Capacitor, Fixed, 130uuf, 500V, ±5%	802175	
C316	Capacitor, Fixed, 200uuf, 500V, ±5%	802168	
C317	Capacitor, Fixed, 160uuf, 500V, ±5%	802560	
C646	Capacitor, Fixed, 39uuf, 500V, ±5%	802338	
*C912	Capacitor, Fixed, 1000uf, 25V	800982	*Used As Input Capacitor With Silicon Rect.
	Function Switch Assembly	500625	
R629	Resistor, Fixed, DC, 93.7K, 1/4W, ±1%	801622	
R640	Resistor, Fixed, DC, 937Ω, 1/4W, ±1%	801621	
	Filter In-Out Switch Ass'y	500626	
	Switch, Level (HI-LO)	202398	

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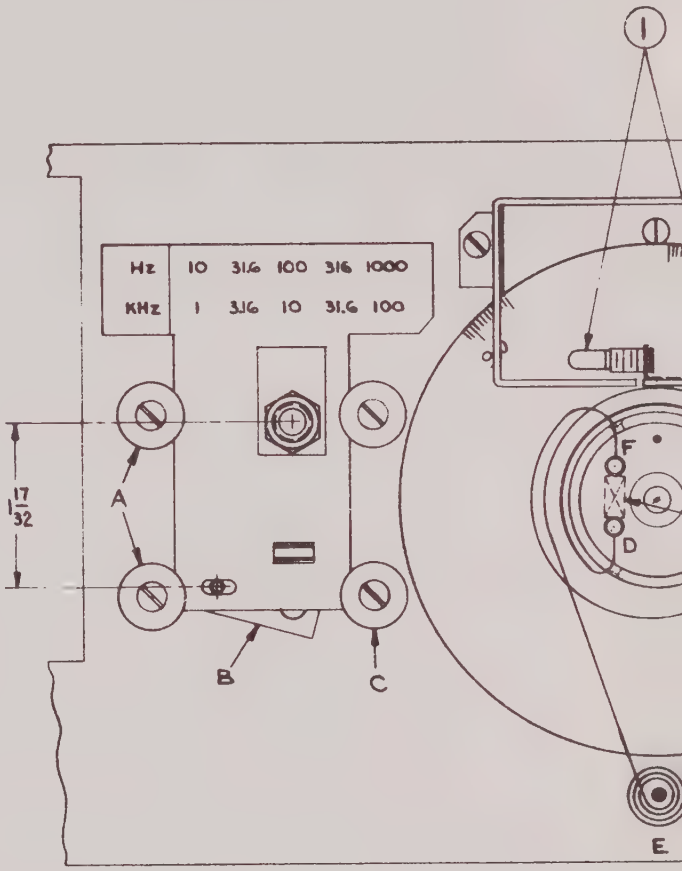

SHOWN WITH FRONT PANEL REMOVED

Item 1.	NAI# 802767	Lamp
Item 2.	NAI# 803614	Spring, Dial
Item 3.	NAI# 900642	Cord, Dial D

FREQUENCY SWITCH SLIDE ADJUSTMENT

(FRONT PANEL REMOVED)

1. Loosen 2 screws supporting adjustable guides "A".
2. Move guides to right against slide and tighten screws.
3. Adjustment is correct when switch may be operated smoothly with a minimum of side to side play of slide.
4. With lower switch (2 position) in extreme clockwise position, adjust block "B" to dimension shown and tighten set screw. Remove single guide "C" and tighten second set screw in block. Replace guide "C".

DRIVE CORD REPLACEMENT, PHASE DIAL

(FRONT PANEL REMOVED)

1. Rotate dial to extreme clockwise position.
2. Starting at spring loop "D", tie one end of cord.
3. Pass other end of cord thru c'sunk hole and wind clockwise approx. 3/4 turn.
4. Pass cord under lower shaft "E" and wind clockwise, 3½ turns.
5. Pass cord over dial hub and wind clockwise approx. 1-1/4 turns; thru second c'sunk hole and then thru spring loop "F". Tie cord while elongating and maintaining tension on spring.
6. Cut off excess cord at knots.
7. When necessary to increase friction, use dial cord dressing N.A.I. #900650.

LAMP REPLACEMENT, PHASE DIAL

(WITH OR WITHOUT FRONT PANEL REMOVED)

Without front panel removed:

1. Remove 2 screws, "G" from rear of sub-panel.
2. Move lamp bracket "H" upward until lamps are accessible for removal.
3. To re-assemble, reverse procedure above.

FIGURE 4.19

SECTION V

TEST AND ALIGNMENT PROCEDURE

It is the purpose of this procedure to assist a qualified technician in the recalibration of the Model 301A Broadband Phase Angle Voltmeter. Under normal circumstances this instrument should require a minimum of service and recalibration.

The test procedure portion of Section V may be used for incoming acceptance test or for periodic calibration checks. It is recommended that the initial periodic check be made every 3 months and future checks be expanded to 6 months or yearly checks.

The alignment procedure portion of Section V may be used for recalibration in the event of a failure which requires the replacement of any module or component in the instrument.

It is recommended that the connection diagram at the rear of Section V be followed carefully with particular attention being paid to shielding and ground techniques.

PART I - TEST PROCEDURE

A. TEST EQUIPMENT REQUIRED

AC Voltmeter	-	Fluke 931A or equivalent
Audio Signal Generator	-	Capable of generating 10Hz to 100KHz
Phase Standard	-	NAI Model 350/351 or Equal capable of generating phase angles 0° through 360° ±0.05° over the frequency range of 10Hz to 25KHz.
Attenuator	-	Kay Electric 31-0 or equiv.
Power Amplifier	-	Krohn-Hite DC10A, or equiv.
Multi-Tester	-	Hewlett Packard 412A Meter or equivalent

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B. GROUND CHECK: The purpose of this test is to check for stray ground paths.

1. With power plug disconnected, remove shorting link from signal ground (black terminal) to chassis ground (metal terminal).

2. Use an ohmmeter with high impedance measurement capability (HP 412A or equivalent).

3. Place ohmmeter leads between signal ground (black terminal) and chassis ground (metal terminal post).

4. Ohmmeter should read 50 megohms or greater.

5. Replace shorting link

C. NOISE CHECK: The following is a procedure for checking the internal noise of the 301A.

1. With power off, check mechanical zero of the meter and adjust if necessary.

2. Turn 301A on and allow it to warm up for 15 minutes.

3. Place short circuits across the REFerence input and SIGnal input terminals.

4. Place the FUNCTION switch in the VM position and the RANGE switch in the 1 milli-volt (.001) position.

5. With the FILTER switch in the OUT position the noise should be no greater than 20 microvolts (1 minor division on the 1 scale)

6. If the instrument is equipped with filters, turn the FILTER switch to the IN position. The noise should be no greater than 30 microvolts (1 1/2 minor division)

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D. REFERENCE CHANNEL SENSITIVITY: This procedure is to ensure proper reference channel sensitivity.

1. Remove the short on the REFerence input terminals.

2. Adjust signal generator to 1KHz and approximately .3 volts RMS output. Apply to REFerence input terminals.

3. Short SIGnal input terminals.

4. Switch FREQUENCY switch to Hz and 316 to 1KHz position.
   Switch FUNCTION switch to 0 degrees.
   Switch FILTER switch to OUT.
   Switch Reference LEVEL switch to LO.

5. Set Reference ADJust potentiometer to give approximately half scale reading on REFerence LEVEL meter.

6. Decrease the reference signal input slowly, readjusting Reference ADJust control to keep pointer of REFerence LEVEL meter on scale. The pointer should be on scale (within the scale markings), until the reference input is reduced to approximately .14 RMS volts.

E. PHASE SENSITIVE NULL CHECK: The purpose of this test is to check for demodulator balance and Reference to Signal channel coupling. Setting of Range switch unimportant. If unit does not meet specification refer to paragraph E of Part II Alignment Procedure.

1. Leave the short circuit across the SIGnal input terminals.

2. Set the Reference LEVEL switch to the LOW position.

3. Set the FILTER switch to the OUT position.

4. Apply 0.5V RMS to the REFerence input at the frequencies called out in Table I.

5. Set FREQUENCY switch as indicated in Table I.

6. Set the Reference LEVEL adjustment for mid scale position.

7. Set Degrees Phase Dial at 0°.

8. Measure the phase sensitive noise with the FUNCTION switch in the 0° position and 90° position. Verify that the noise is less than that listed in Table I.

TABLE I

Signal Frequency	FREQUENCY Switch	0° FUNCTION Switch	90° FUNCTION Switch
10Hz	10 - 31.6 Hz	Less Than 10μv	Less Than 10μv
1KHz	316 - 1 KHz	Less Than 2μv	Less Than 2μv
100KHz	31.6 - 100 KHz	Less Than 10μv	Less Than 10μv

F. VOLTAGE ACCURACY: This test checks the accuracy of the voltmeter mode of operation. (See paragraph C and I of Part II alignment procedure, if unit does not meet specifications).

1. Set the FUNCTION switch in the VM position.

2. Remove the short from the SIGnal input terminals.

3. Inject the signals of the amplitudes and frequencies listed in Table II into the SIGnal Input terminals. Note meter deflections. Indications should be within ±2% of full scale on each range.

TABLE II

Input Signal (RMS)	10Hz	1KHz	100KHz	RANGE Switch Setting
900μv				1mv (.001)
2.7mv				3mv (.003)
9mv				10mv (.01)
27mv				30mv (.03)
90mv				100mv (0.1)
270mv				300mv (0.3)
0.9V				1V (1)
2.7V				3V (3)
9.0V				10V (10)
27V				30V (30)
90V				100V (100)
270V				300V (300)

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NOTE: ZERO CONTROL OPERATIONS

Before continuing further with the test, review the following points:

1. Whenever phase sensitive measurements are being made, it is necessary to zero and equal the Model 301A each time the frequency is changed. This is necessary in the following test, and should be done when the frequency is changed. This will be referred to as EQUAL or ZERO.

2. EQUAL

   This is done by adjusting the Reference Signal Level to obtain an on-sclae reading on the REFerence LEVEL Meter. Depress the EQUAL Switch and adjust the EQUAL control so that there is no change in REFerence LEVEL when the EQUAL Switch is normal or depressed.

3. ZERO

   Depress the ZERO Switch and adjust the ZERO control to read a null on the voltmeter.

G. ZERO SWITCH TEST (See Paragraph G of Alignment Procedure, Part II, if the unit does not meet specifications)

FILTER OUT: This procedure will insure that depressing the ZERO Switch will insert a voltage having the same phase as the reference into the Signal Channel.

1. Connect Signal Generator output to REFerence and SIGnal terminals of 301A.

2. Set FUNCTION Switch to 0° and DEGREES Phase Dial to 0°.

3. Set FILTER Switch to OUT.

4. Set RANGE Switch to 1.0 (1) volt.

5. Set FREQUENCY Switch to KHz and 3.16 to 10KHz.

6. Set Signal Generator to 8KHz at .6 volts RMS.

7. Set REFerence LEVEL Switch to LO and adjust REFerence ADJust potentiometer to give approximately half-scale.

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reading on REFerence LEVEL meter.

8. Switch FUNCTION Switch to 90°, set RANGE Switch to .1 volts (.1) (6 X overload). Voltmeter will read approximately a null.

9. Set ZERO ADJust for a null without depressing the ZERO switch.

10. Depress ZERO Switch. The meter should read zero (0) ±1/4 minor division as indicated on the meter.

FILTER IN POSITION

11. Place short circuit between Pins 2 and 8 of the octal filter socket. (Remove filters if they are present).

12. Set FILTER Switch to IN position.

13. Set ZERO ADJust for a null without depressing the ZERO Switch.

14. Depress ZERO Switch. The meter should read zero (0) ±1/4 minor division as indicated on the meter.

15. Remove jumpers installed in step 11.

10Hz and 100KHz TEST (Filter OUT Position)

16. Repeat steps 1 to 8 at 10Hz with FREQUENCY Switch in the appropriate position, 10-31.6Hz.

17. Depress ZERO Switch and adjust ZERO control for a null. Release ZERO Switch. Deviation should not be greater than ±0.3° on the DEGREES Phase Dial.

18. Repeat above at 100KHz, placing FREQUENCY Switch in the 31.6 - 100KHz position. Deviation should not be greater than ±0.3° on the DEGREES Phase Dial.

H. REFERENCE HI-LO ATTENUATOR TEST (See Paragraph H of Alignment Procedure, Part II, if the unit does not meet specifications)

This procedure will check the 30:1 reference input attenuator for minimum phase difference between the HI or LO positions of the REFerence LEVEL Switch.

1. Set FREQUENCY Switch to KHz and 1-3.16KHz position.
   Set REFerence HI-LO Switch to LO position.
   Set REFerence LEVEL ADJust to full ccw.
   Set FUNCTION Selector to 90° position.
   Set RANGE Switch to 1 volt (1) range.
   Set FILTER IN-OUT Switch to OUT position.
   Set DEGREE Phase Dial to 0°.

2. Set Generator to 1.6KHz and adjust output to give approximately half scale reading on the REFerence LEVEL Meter.

3. Null the voltmeter with ZERO Control without depressing ZERO Switch.

4. Set REFerence HI-LO Switch to HI and turn REFerence LEVEL ADJust fully clockwise. This should result in an on-scale reading of the REFerence LEVEL Meter.

5. The voltmeter should read a null (as in step 3) ±1/4 minor division as indicated on the meter.

I. HIGH SIGNAL RANGE TEST (See Paragraph I of Alignment Procedure, Part II, if the unit does not meet specifications)

This procedure will check the 1000:1 signal input attenuator of the 301A for correct attenuation and minimum phase shift.

1. Set FREQUENCY Switch to Hz and 316 - 1KHz position.

2. Set RANGE Switch to 3 volts (3).

3. Set FUNCTION Switch to 0°.
   Set DEGREES Phase Dial to 0°.

4. Set REFerence LEVEL Switch to the HIGH position.

5. Adjust Signal Generator for a 10 volt RMS output at 600Hz and feed this into the REFerence Terminals of the 301A and also into an Attenuator Box or Ratio Box as shown in Figure 5.3A.

6. Set Reference ADJust potentiometer to give approximately half scale reading on REFerence LEVEL meter.

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7. Adjust Attenuator Box for a 3 milli-volt RMS output. Switch the RANGE Switch of the 301A to the 1 milli-volt (.001) position (3 x overload).

8. Switch FUNCTION Switch to 90° position.

9. Null the 301A with the ZERO Control without depressing the ZERO Switch.

10. Switch the RANGE Switch to the 1 Volt (1) position and adjust attenuator box for a 3 volt RMS output.

11. The 301A Meter should now be at a null +1/4 minor division as indicated on the meter.

J. RANGE SWITCH ARM CAPACITIVE TRIM TEST

The purpose of this test is to check the compensation for the difference in capacitance of the RANGE Switch arm at 100KHz.

1. The setup for this check is the same as the above except that a Ratio Box should not be used at 100KC.

2. Set FREQUENCY Switch of the 301A to KHz, 31.6-100.position

3. Set oscillator for 100KHz at 10 volts RMS output and feed into the REFerence terminals of the 301A and also into the Attenuator Box.

4. Adjust output of attenuator for 1 volt RMS and feed this into SIGnal terminals of 301A.

5. Set FUNCTION Switch to 90°.

6. Set RANGE Switch to 300mv (.3) range (3 X overload).

7. Set REFerence LEVEL Switch to HIGH position and adjust REFerence ADJust control for approximately mid scale.

8. Null the 301A without depressing ZERO Switch.

9. Adjust Attenuator Box for a 10mv RMS output.

NORTH ATLANTIC *industries, inc.*
200 terminal drive, plainview, n. y. *OVerbrook 1-8600*

10. Switch RANGE Switch to 3mv (.003) position.

11. The 301A should read a null ±1/4 minor division as indicated on the meter.

K. PHASE ACCURACY CHECK: The purpose of the following test is to verify that the 301A is operating within its rated phase accuracy at several frequencies.

1. Set the REFerence LEVEL Switch in the LO position.

2. Set the FILTER Switch in the OUT position.

3. Set the RANGE Switch to the 1mv (.001) position.

4. Inject a reference signal input of 150mv RMS at the frequencies listed in Table III using an Attenuator Box or a Ratio Box.

5. Inject a signal input of 10mv RMS, phase shifted by the various angles listed in Table III and at the various frequencies listed in Table III. These input angles must be accurate to ±0.05°.

6. Adjust the FUNCTION Switch to the setting called out in Table III.

7. Adjust the DEGREES Phase Dial for a null reading on the meter. (Note: At each frequency it will be necessary to use the EQUAL and ZERO switches according to the instructions in the NOTE preceding paragraph G, Page 5.5

8. The DEGREES Phase Dial reading should be within the following accuracy.

At 100Hz	±0.25°
At 1KHz	±0.25°
At 10KHz	±0.25°

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200 terminal drive, plainview, n. y. OVerbrook 1-8600

TABLE III

ANGLE	LOW BAND 100Hz	LOW BAND 1KHz	HI BAND 1KHz	HI BAND 10KHz	FUNCTION SWITCH SETTING
0					90°
10					90°
20					90°
30					90°
40					90°
45					90°
50					90°
60					90°
70					90°
80					90°
90					90°
135					180°
180					180°
225					270°
270					270°
315					0°
360					0°

L. OVERLOAD CHECK: The purpose of this test is to verify the correct operation of the overload warning indicator. (See paragraph K of Alignment Procedure, Part II, if unit does not meet specifications)

1. Set the FUNCTION Switch to the 90° position. Set the DEGREES Phase Dial to 0°.

2. Set the RANGE Switch to the 100mv (.1) position.

3. Inject 1KHz, 1V RMS signal into the REFerence and SIGnal input terminals.

4. Set REFerence switch to LO position and REFerence ADJust control for half scale reading on REFerence LEVEL meter.

5. Slowly increase the amplitude of the signal until the overload light starts to blink. This should occur at 1.1V ±0.05V RMS.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

PART II - ALIGNMENT PROCEDURE

A. INITIAL POWER SUPPLY VOLTAGE CHECK

1. Short REFerence and SIGnal input terminals. Short signal ground post and chassis ground (metal post). All input sources and test equipment should be referenced to this ground only.

2. Third prong on 301A power plug must be connected to a house ground.

3. Apply power to Phase Angle Voltmeter. Observe that filaments and pilot lights are on. Make sure that neon light on power supply ignites within 1 minute.

4. All instruments have been carefully factory inspected and calibrated. The power supply should have an output between the limits listed below. All readings are with respect to chassis ground.

Pin	DC Volts	Nominal Ripple (RMS)
*10	-79 to -81	Approx. 1.5mv
11	+255 to +265	Approx. 2mv
12	+185 to +205	Approx. 12 volts
15	+250 to +300	Approx. 90mv
8 & 9	+12 to +12.6	Approx. 3mv
16	-125 to -135	Approx. 200mv

*In the event that the -80 volts is adjusted, the +260 volt (pin 11) and the 12.3V DC (Pins 8 and 9) must also be rechecked, as these two supplies are derived from the -80V supply. It is suggested that the -80V supply always be checked first. See Figure 4.15, Page 4.49 for pin locations on the power supply Assembly #500083.

NOTE: To obtain access to the power supply, it is necessary to remove the rear panel. This may be accomplished by the removal of 8 screws, 2 at each end and 4 securing the panel to the fuse/line cord bracket.

5. Due to tube ageing, etc., the instrument may not remain within the above limits, and adjustment should be made. The appropriate resistors for adjusting each output are listed below. The DC amplitude adjust is to be used to change the DC voltage level. The AC ripple adjust is to be used to lower the particular ripple level. See Figure 4.15 page 4.49 for resistor location.

Pin	DC Amplitude Adjust	Ripple Adjust
10	R908 (27K nom.)	R912 (33K nom.) and/or R910 (22Ω)
11	R938 (1.2K nom.)	R937 (240K nom.)
8 and 9	R930 (39K nom.)	No Adj.

NOTE: The resistor values indicated are nominal values only. They should be selected to produce the desired voltages.

B. PHASE DIAL ALIGNMENT ON PHASE SHIFTER POT, R8

The following is the procedure for mechanically aligning the DEGREES Phase Dial on the shaft of the phase shift pot (R644). This is necessary in the event that a DEGREES Phase Dial, a phase pot, or both, are disassembled or replaced. (See Figure 4.19 for disassembly instructions.) The 0° and 90° points on the dial must be aligned to coincide with the taps (terminals 4 and 5) of the pot.

CAUTION: Use only a low current ohmmeter (ie., HP412) as damage to the precision phase pot can occur if excessive voltage is applied.

1. Turn power off.

2. Set FUNCTION selector to any phase sensitive position.

3. Place one lead of the ohmmeter on pin 2 of the phase pot, which is the wiper. Place the other lead on pin 5 of the pot, which is the 0° tap. Rotate phase pot shaft until a null

is indicated on the ohmmeter. The wiper is now located at the 0° tap of the pot and the DEGREES Phase Dial should now be at 0°.

NOTE: For field alignment check 90° null before resetting DEGREES Phase Dial.

If the DEGREES Phase Dial does not indicate 0°, loosen both allen screws that hold the phase dial to the shaft. These screws are accessible from the bottom of the unit. Move DEGREES Phase Dial by hand so that when a null is indicated on the ohmmeter, the dial is at exactly 0°. When they align, tighten allen screws.

Remove the ohmmeter lead from pin 5 and place it on pin 4, which is the 90° tap. Rotate DEGREES Phase Dial until a null occurs on the ohmmeter. The DEGREES Phase Dial should now read exactly 90°; if not, reposition dial so as to achieve the best compromise reading between the two taps. Check the 0° and 90° alignment of R644B in the same manner without slipping the dial on the pot shaft.

The maximum error should not exceed .05° on the DEGREES Phase Dial. All errors should be divided equally between all 4 tap points. Fully tighten the set screws and recheck to make sure dial has not slipped during tightening.

C. VOLTAGE RANGE ADJUSTMENT (LOW RANGE)

The purpose of this adjustment is to calibrate the full scale voltage sensitivity of the Signal Channel. This calibration will adjust the sensitivity of the 1mv through 300mv ranges.

1. Connect Signal Generator to the Fluke AC VM and input of the Kay electric attenuator. (If oscillator used is capable of being varied from 1mv to 300mv, no attenuator is needed).

2. Connect output of attenuator to the SIGnal input of the 301A.

3. Switch FUNCTION switch to VM. Switch FILTER switch to OUT.

4. Adjust Signal Generator to 1KHz and 1 volt RMS output, (As read on AC VM).

5. Set attenuator to 100 milli-volts output.

6. Set RANGE switch to 100 milli-volts (.1) range. Adjust

calibrate potentiometer, R242 on back panel, for exactly 100 milli-volts on 301A meter. (See Figure 5.1) NOTE: In early units, rear panel must be removed for access.

7. Repeat Steps 1 through 6 at 10Hz, 50KHz, and 100KHz.

8. If the readings are not within ±2% at 100KHz, select C219 on the Signal Amplifier to bring the reading within spec. An increase of capacity will increase gain (approximately 1% change for each 100pf.) See Figure 4.2 Page for parts location on Signal Amplifier P/N 500047.

9. If the readings are not within ±2% of 10Hz, adjust R215 on Signal Amplifier. See Figure 4.2 Page 4.12 for parts location on Signal Amplifier P/N 500047.

D. REFERENCE PRE-AMP ADJUSTMENT

(This should be done any time Tube V-301 is changed). This procedure will adjust the DC voltage across the REFerence ADJust.Potentiometer to zero and ensure smooth operation of this control.

1. Short the REFerence input terminals.

2. Adjust R309 to cause the DC voltage on Pin 16 of Ref. Pre-Amp. (#500086) to equal 0V ±30mv DC. (R309 is located on the reference pre-amp board.) Split the error when the HI-Lo switch is switched to HI and LO position. See Figure 4.3 Page 4.16 for location of parts).

E. REFERENCE COMMON MODE ADJUSTMENTS

This procedure will balance the push-pull output voltage of the Reference Drive Amplifier (#500050) so that the voltmeter will read a null with a normal reference input and zero signal input. This balance will be done at 1KC, 100KHz and 10Hz.

1. Adjust Signal Generator to 1KHz and approximately .3 volts RMS output. Apply to REFerence input terminals.

2. Short SIGnal input terminals.

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200 terminal drive, plainview, n. y. OVerbrook 1-8600

3. Switch FREQUENCY Switch to Hz and 316 to 1KHz position.
Switch FUNCTION Switch to 0 degrees
Switch FILTER switch to OUT
Switch REFerence LEVEL Switch to LO

4. Adjust REFerence ADJust potentiometer to give approximately half scale reading on REFerence LEVEL meter.

5. Voltmeter should read 0uv ±2uv indpendent of RANGE Switch or Phase Snesitive position of FUNCTION Switch. If this reading is exceeded, it will be necessary to trim, depending on direction of error, either R847 or R850 located on Reference Drive Amplifier. Terminals have been provided to accommodate this trim. If error is to left, trim R850. If error is to right trim R847. (See Figure 4.14 Page 4.43 for location of parts.

6. Adjust Signal Generator to 100KHz and repeat 1 through 4 of above. Note that FREQUENCY Switch should be on KHz and 31.6 - 100KHz.

7. Adjust C807 on the Reference Drive Amplifier for a null ±10uv. Divide the error when the FUNCTION Switch is switch between 0° and 90° position.

8. Set FREQUENCY Switch to Hz and 10 - 31.6. Adjust signal generator to 10Hz. Repeat steps 1 through 4 of above.

9. Voltmeter should read 0 ±10uv independent of RANGE switch or Phase Sensitive position of FUNCTION switch. If this reading is exceeded, adjust R831 or R858 as required for a null on REFerence Drive Amplifier.

NOTE: Do not go below 750K for R831 and R858. If it becomes necessary to go below 750K replace V801 and V802.

F. ZERO-EQUAL CONTROL OPERATIONS

Before continuing further with the tests, review the following points:

1. Whenever phase sensitive measurements are being made, it is necessary to zero and equal the Model 301A each time the frequency is changed. This is necessary in the following test. and should be done when the frequency is changed.

This will be referred to as EQUAL or ZERO.

2. EQUAL

This is done by adjusting the Reference Signal Level to obtain an on-scale reading on the REFerence LEVEL Meter. Depress the EQUAL Switch and adjust the EQUAL control so that there is no change in reference level when the EQUAL Switch is normal or depressed.

3. ZERO

Depress the ZERO Switch and adjust the ZERO control to read a null on the voltmeter.

G. ZERO SWITCH ADJUSTMENT

FILTER OUT

This procedure will ensure that depressing the ZERO Switch will insert a voltage having the same phase as the reference into the Signal Channel. This is done by adjustment of the broadband attenuator which samples the reference signal.

1. Connect Signal Generator output to REFerence and SIGnal terminals of 301A

2. Set FUNCTION Switch to 0° and DEGREES Phase Dial to 0°.

3. Set FILTER Switch to OUT

4. Set RANGE Switch to 1.0 (1) volts.

5. Set FREQUENCY Switch to KHz and 3.16 to 10KHz.

6. Set Signal Generator to 8KHz at .6 volt RMS.

7. Set REFerence LEVEL Switch to LO and adjust REFerence ADJust Potentiometer to give approximately half-scale reading on REFerence LEVEL Meter.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

8. Switch FUNCTION Switch to 90°, set RANGE Switch to .1 volts (.1) (6 x overload). Voltmeter will read approximately a null.

9. Set ZERO ADJust for a null without depressing the ZERO Switch.

10. Depress ZERO Switch and adjust C308 for a null (See Figure 4.3) located on REF Pre-Amp Board (Inside the shield).

FILTER IN POSITION

11. Place short circuit into filter sockets between Pins 2 and 8. (Remove filters if they are present).

12. Set FILTER Switch to IN position.

13. Adjust ZERO ADJust Control for a null without depressing the ZERO Switch.

14. Depress ZERO Switch and trim capacitor C102 on grid of V102 for a null (See Figure 5.2) located on Signal Pre-Amp Board 500620.

15. Remove jumpers installed in step 11.

10Hz and 100KHz ADJUSTMENT (Filter OUT Position)

16. Repeat steps 1 to 4 at 10Hz with FREQUENCY Switch in the appropriate position, 10 - 31.6Hz.

17. Depress ZERO switch and adjust ZERO control for a null. Release ZERO switch. Trim out offset, if greater than 0.3° at 10Hz, by placing a high value resistor (5 to 30 meg.) across input to Signal Amplifier (Pins 17 and 18) or Reference Amplifier (Pins 11 and 12) depending on direction of error.

18. Repeat above at 100KHz, placing FREQUENCY switch in the 31.6 - 100KHz position. Trim out offset if any by placing a capacitor (Nom. 20pf) from the cathode of either V101 (Pin 7)or V301 (Pin 3) to ground depending on direction of error. (This may be placed directly on the pins of the tuve socket).

H. REFERENCE HI-LO ATTENUATOR

This procedure will adjust the 30:1 reference input attenuator so that there is no phase difference between the HI or LO positions of the REFerence LEVEL Switch.

1. Set FREQUENCY Switch to KHz and 1 - 3.16KHz position.
   Set REFerence HI-LO Switch to LO position.
   Set REFerence ADJust control to full ccw.
   Set FUNCTION Selector to 90° position.
   Set RANGE Switch to 1 volt (1) range.
   Set FILTER IN-OUT Switch to OUT position.

2. Set Generator to 1.6KHz, feed into Signal and Reference channels and adjust Signal Generator output to give approximately half scale reading on the REFerence LEVEL meter.

3. Null the voltmeter with ZERO control without depressing ZERO Switch.

4. Set REFerence HI-LO Switch to HI and turn REFerence ADJust control fully clockwise. This should result in an on-scale reading of the REFerence LEVEL Meter.

5. Adjust C318 on Reference Pre-Amplifier (500086) for a null on the 301A meter. (See Figure 4.3, page 4.16 for part locations).

I. HIGH SIGNAL RANGE ADJUSTMENT

This procedure will adjust the 1000:1 signal input attenuator of the 301A so that the attenuation is correct at all frequencies and there is no phase shift across the attenuator.

1. Set FREQUENCY Switch to Hz and 316 - 1KHz

2. Set RANGE Switch to 3 volts (3)

3. Set FUNCTION Switch to 0°.

4. Set REFerence LEVEL Switch to the HIGH position.

5. Adjust Signal Generator for a 10 volt RMS output at 600Hz and feed this into the REFerence Terminals of the 301A and also into an attenuator box or Ratio Box as shown in Figure 5.3A

6. Set Reference ADJust potentiometer to give approximately half scale reading on REFerence LEVEL Meter.

7. Adjust Attenuator Box for a 3 milli-volt RMS output. Switch the RANGE Switch of the 301A to the 1 milli-volt (.001) position (3 X overload).

8. Switch FUNCTION Switch to 90° position.

9. Null the 301A with the ZERO Control without depressing the ZERO Switch.

10. Switch the RANGE Switch to the 1 volt (1) position and adjust attenuator box for a 3 volt output.

11. The 301A meter should now be at a null, if not adjust C1301 which is mounted on the RANGE Switch (Refer to Figure 5.1) for a null.

J. RANGE SWITCH ARM CAPACITIVE TRIM

The purpose of this trim is to compensate for the difference in capacitance of the RANGE Switch arm at 100KHz.

1. The setup for this check is the same as the above except that a Ratio Box should not be used at 100KC.

2. Set FREQUENCY Switch of the 301A to KHz 31.6 - 100.

3. Set oscillator for 100KHz at 10 volts RMS output and feed into the REFerence terminals of the 301A and also into the Attenuator Box.

4. Adjust output of attenuator for 1 volt RMS and feed this into SIGnal terminals of 301A.

5. Set FUNCTION Switch to 90°. **Set DEGREES Phase Dial to 0°.**

6. Set RANGE Switch to 300mv (.3) Range (3 X overload)

7. Set REFerence LEVEL Switch to HIGH position and adjust REFerence ADJust control for approximately mid scale.

8. Null the 301A without depressing ZERO Switch.

9. Adjust attenuator box for a 10mv RMS output.

10. Switch RANGE Switch to 3mv (.003) position.

11. The 301A should read a null. If not, adjust C1302 on RANGE switch (Refer to Figure 5.1) for a null.

K. OVERLOAD ADJUSTMENT

This procedure adjusts the overload light, so that it starts to blink at 11X overload.

1. Set FUNCTION Switch to 90°.

2. Set FILTER Switch to OUT position.

3. Set RANGE Switch to 100 milli-volts (.1)

4. Set FREQUENCY Switch to the 1 to 3.16KHz position.

5. Set REFerence LEVEL Switch to LO position and REFerence ADJust for half-scale reading on REFerence LEVEL Meter.

6. Apply an input signal of 1.1V RMS at 1KHz into SIGnal and REFerence terminals.

7. Adjust overload potentiometer (R1003) so that overload light just starts to blink. (See Figure 5.1, Page 5.29)

8. It may be necessary to adjust R229 of Signal Amplifier Board (#500047) for proper overload indication at 10Hz. (See Figure 4.2)

L. PHASE NETWORK ALIGNMENT

The purpose of this alignment is to calibrate the 90° phase shifters in the 301A. In order to do this, it is necessary to have precision 90° sources available at the various frequencies corresponding to the networks being trimmed. A simple circuit for generating 0° and 90° at one frequency is shown below. Other methods of generating phase angles are shown in the phase generation circuits at the end of this section.

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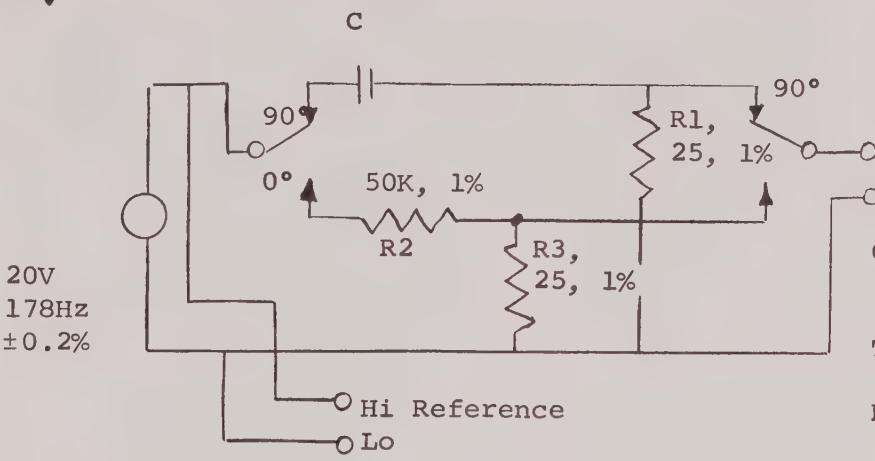
200 terminal drive, plainview, n. y. OVerbrook 1-8600

STANDARD NETWORK



Since this network will pass harmonics of the signal frequency with less attenuation than the signal frequency itself, a low distortion oscillator must be used. C must be a polystyrene capacitor with a dissipation factor of less than 0.02%. This will allow a phase shift to within 0.011° of 90°. Care must also be taken to reduce the capacity across R2 to a minimum. For this purpose, it would be wise to use two separate toggle switches as shown above. For example, 1pf across R2 can cause 0.18° of phase shift at 10KHz. For this reason, it is also best to use metal film resistors.

Tables IV and V show values of C for the frequencies of alignment of component to be trimmed, as well as location and number. (See Figures 4.5 thru 4.12)

TABLE IV

(ALL UNITS PRIOR TO S/N 8251)

Band #	Freq. Band	Freq. (±0.2%) AT Which Trim Is Performed	C-STD Network	Comp. To Be Trim'd On S6	Where to Trim On Bd 3 of S6 Term.
2	31.6 - 100Hz	56.2Hz	.057uf	C633	E-F
3	100 - 316Hz	178Hz	.018uf	C634	G-H
4	316 - 1000Hz	562Hz	.0057uf	C635	J-K
5	1000Hz - 3.16KHz	1.78KHz	.0018uf	C632	C-D
6	3.16 - 10KHz	5.62KHz	.00057uf	R605	A-B

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

TABLE V

(ALL UNITS AFTER S/N 8251)

Band #	Freq. Band	Freq. (±0.2%) At Which Trim Is Performed	C-STD Network	Comp. To Be Trimmed	Component To Be Added on TB6A
2	31.6 - 100Hz	56.2Hz	.057uf	C633	C633A
3	100 - 316Hz	178Hz	.018uf	C634	C634A
4	316 - 1000Hz	562Hz	.0057uf	C635	C635A
5	1000Hz - 3.16KHz	1.78Hz	.0018uf	C632	C632A
6	3.16 - 10KHz	5.62KHz	.0057uf	R605	R605A

The procedure for alignment is as follows:

1. Set RANGE Switch to 1mv (.001) position (10x overload). Set FREQUENCY Switch to appropriate position for frequency to be calibrated. Set FILTER IN-OUT switch to OUT position. Set FUNCTION Switch to 0° position. Set **DEGREES** Phase Dial to 0°.

2. Apply 20V RMS (frequency to be calibrated) to the standard network and the REFerence input terminals. Apply 10mv output of standard network to SIGnal input terminals.

3. Set REFERENCE HI-LO switch to HI position and set REFerence LEVEL ADJust control to approximately mid-scale on the REFerence LEVEL meter.

4. Set the standard switches to the 90° position.

5. Null voltmeter with ZERO control without depressing ZERO switch.

6. Switch standard switches to the 0° position, and the FUNCTION switch of the 301A to the 90° position.

7. If step 6 does not result in a null within ±.1°, then a trim component, as shown in the above tables, must be placed on the appropriate pins of S6, Board #3 or on TB6A depending on serial number of unit.

NORTH ATLANTIC industries, inc.

200 terminal drive, plainview, n. y. OVerbrook 1-8600

NOTE: In each case, the trim components called out are located on TB6A (Figure 4.12, Page 4.35) in instruments with serial numbers 8251 and up. In instruments with earlier serial numbers, these trim components are located on S6 (FREQUENCY Switch) deck #3 (Figure 4.10, Page 4.31).

8. This procedure must first be performed in Bands 2, 3, and 4, trimming C633, C634, C635 respectively. Band 6 must then be trimmed with R605. Finally, Band 5 must be trimmed with C632. The order for trimming must be followed carefully.

9. Example: Since Band 2 is to be calibrated first, apply 20V RMS at a frequency of 56.2Hz to the standard network and to the REFerence input terminals of the 301A. Apply the output of standard network to SIGnal input terminals. Switch the FREQUENCY switch to the Hz position and the frequency band to 31.6 - 100Hz position.

   STEP 1 - REFerence HI-LO switch to HI position and set REFerence LEVEL ADJust control for approximately mid-scale on REFerence LEVEL meter.

   STEP #2 - Set the switches on the standard network to the 90° position. With the FUNCTION switch of the 301A in the 0° position, null the voltmeter with the ZERO control without depressing the ZERO switch.

   STEP #3 - Now set the switches of the standard network to the 0° position and the FUNCTION switch of the 301A to the 90° position. If the unit is properly calibrated the signal meter should indicate a null within ±.1°.

   STEP #4 - If the signal meter indicates a negative error, add additional capacitance across C633 and if the error is positive, decrease the value of capacitance. C633A is included for this purpose.

10. After band 2 is calibrated, repeat the above example for band 3 at 178Hz and then band 4 at 562Hz, always keeping in mind that when you change frequency a new standard network must be used. If band 3 needs trimming, trim C634 by either adding or subtracting capacity depending on direction of error. If band 4 needs trimming, trim C635 by adding or subtracting capacity. C634A and C635A are included for this purpose.

11. Now that bands 2, 3, and 4 have been calibrated in the Hz position, switch the FREQUENCY selector switch to the KHz position and the band selector to the 3.16 - 10KHz position (Band 6). Now feed 20 volts RMS at 5.62KHz into the REFerence channel and standard network. Repeat steps 1, 2, and 3 above. If a null within ±.1° is not indicated, it will be necessary to trim R605. If the error is to the left, increase the value of the resistance and if the error is to the right, decrease the value of resistance. R605A is included for this trim.

12. Finally, Band 5 is to be calibrated at 1.78KHz following the above procedure, trimming C632 for a null. If the error is to the left, add capacity and if error is to the right, decrease the capacity. C632A is included for this trim.

M. SPECIAL PHASE TRIM FOR INDIVIDUAL BAND

The phase network alignment procedure described in the preceding section results in the alignemnt of the 90° networks on all frequency bands. It is noted that each of the calibrations is done at the geometric mean frequency of the frequency band being aligned and the variation within the band is generally less than 0.1°. It is also noted that bands 1, 7, and 8 are not trimmed. No trimming is necessary on these bands because trimming bands 2, 3, 4, 5 and 6 will automatically calibrate bands 1, 7, and 8. Due to the nature of the special networks and switching used, the calibration of one band will somewhat affect others.

In certain applications it may be desirable to calibrate a particular frequency or band without affecting the complementary band associated with it. Thus, the instrument has been designed to provide a means for inserting a phase trim on any four of the eight bands, provided that the ones trimmed are not complementary. This is, either bands 1 or 5, 2 or 6, 3 or 7, and 4 or 8. If the instrument is so calibrated (by request) the procedure for changing or re-adjusting this trim is as follows.

It will be noted that S6 Board #3 uses six terminals which are marked N, P, S, T, U, V. (Terminals Q and R are intermediate and included for the sake of convenience). These terminals are connected, by means of the FREQUENCY switch, so as to allow the special band trimming noted above. On units after Serial

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

Number 8251 these terminals have been brought out on TB6A.

NOTE: Before attempting this trim, re-read carefully Phase Network Alignment Procedure in the preceding section.

(DO NOT TOUCH PREVIOUS NETWORK TRIMS)

1. Using the standard test network outlined above, select values of C and R1 that will give 10mv RMS output and 90° phase shift at the desired frequency (or band) Using band 1 (10Hz to 31.6Hz) as an example.

2. Set the FREQUENCY Switch to the 10Hz to 31.6Hz range.

3. Set the RANGE Switch to the 1mv (.001) range.

4. Set the FUNCTION Switch to 0°. Set DEGREES Phase Dial to 0°.

5. Set the REFERENCE Switch to the appropriate position.

6. Adjust REFerence ADJust potentiometer to give half scale reading on REFerence LEVEL Meter.

7. To bring the 301A to exact null, temporarily connect a capacitor or resistor as needed between terminals P and S, Board #3 of S6 (FREQUENCY Switch).

8. After selecting the proper value in step 7, permanently install this component between terminals P and S.

9. The procedure used in Steps 7 and 8 above may be used in any of the bands using terminals S, T, U, or V and Terminal P consecutively for trimming bands 1, 2, 3, and 4 respectively.

10. The high bands are trimmed in the same manner except Terminal N is used in place of Terminal P. Pins S, T, U, or V may be used to trim bands 5, 6, 7, or 8 respectively.

NOTE: HI or LO bands may be trimmed, but not both simultaneously.

NORTH ATLANTIC industries, inc.
200 terminal drive, plainview, n. y. OVerbrook 1-8600

N. PHASE POTENTIOMETER TRIMMING

This trim is necessary to compensate for the effects of capacity to ground on the phase potentiometer arm. This effect is maximum when the DEGREES Phase Dial is at 45° and the frequency is at the upper end of the Hz and KHz ranges.

1. Set the FREQUENCY Switch to Hz and 316 - 1KHz position.
   Set FUNCTION Switch to 90°
   Set FILTER IN-OUT Switch to OUT position

2. Set Signal Generator to 1KHz ±.2% and connect it to the reference terminals of the 301A and to a zero phase shift network. Set the network for a 10mv RMS output and feed this into the SIGnal input terminals of the 301A. If a phase generator is used (NAI Model 350/351) instead of the phase shift network, set the output of the phase generator for 0°.

3. Switch RANGE Switch to 1mv (.001) range (10 x overload)

4. Set REFERENCE switch to HI and adjust REFerence LEVEL ADJust control for mid-scale reading on REFerence LEVEL meter.

5. Adjust EQUAL control as accurately as possible.

6. Adjust 301A for null with ZERO control, without depressing ZERO switch.

7. Disconnect the signal generator from the attenuator, if one was used, and connect it to an accurate 45° ±0.05° network, which has an output of 10mv RMS (A network of this sort is shown below). Connect the output of this network to the signal input terminals leaving the REFerence terminals connected to the signal generator. If a phase generator is used, set the output of the phase generator to 45°.

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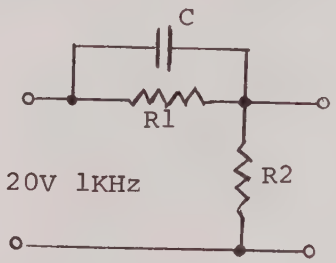
8. Rotate DEGREES Phase Dial to 45° and adjust C645 for a null on the voltmeter. C645 is located on the first deck of the FREQUENCY switch and is accessbile from the top of the 301A. An insulated alignment tool is needed for this adjustment.



9. Repeat steps 1 thru 7 of the above, changing the FREQUENCY switch to the 100 - 316Hz position and change the frequency of the oscillator to 220Hz (±.2%). Keep in mind that at this frequency a different 45° network is needed.

10. Rotate DEGREES Phase Dial to 45° and trim, if necessary, either R657 or R658 (depending on direction of error) for a null within ±.1°. R657 is located on the first deck of the frequency switch and R658 is located on the third deck of the frequency switch (Figure 4.10). On units whose serial number is above 8251, these points are located on TB6A (Figure 4.12)

11. If it was necessary to trim R657 or R658 at 220Hz at 45°, recheck 45° at 1KHz as the two interact.

12. Repeat steps 1 thru 7 changing the FREQUENCY switch to the 1-3.16KHz position and changing the frequency of the oscillator to 1.78KHz (±.2%). Again keep in mind that at this frequency a different 45° network is needed.

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13. Rotate DEGREES Phase Dial to 45° and trim, if necessary, either R656 or R659 (depending on direction of error) for a null within ±.1°. R656 is located on the first deck of the FREQUENCY switch and R659 is located on the third deck. On units above serial number 8251 these points are located on TB6A.

14. If it is desired to achieve maximum 315° accuracy, and a phase generator with a -45° ±0.05° is available, the following procedure should be followed. Apply a 220Hz, -45° ±0.05° 315° 10mv RMS signal input and the 301A as in 9 and 10 above, except the FUNCTION Switch is 0°.

    If a null within ±.1° is not indicated, trim out the error by placing resistor R648 (6-30K) across R622. Repeat the above procedure at 1.78KHz, trimming out the error by placing resistor R649 (1-10K) across R626, if required.

    Resistors R624 and R626 are located on TB6 (See Figure 4.11).

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P. Phase Angle Generation

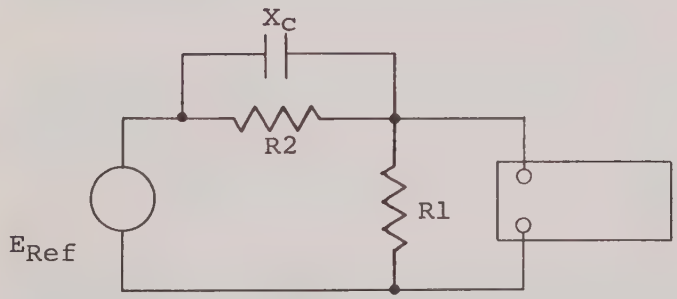
The test procedure requires that phase angles other than 90° or 0° be used for some checks. Commercially available phase angle generating equipment may be used to perform these tests. However, if commercial equipment is not available, it is suggested that the following methods be used.

RC Passive Phase Shifter - Precise phase angles can be generated using the circuit configuration shown below. These networks are very useful and are simple to construct. They do require, however, accurate measurement of component values. They may be constructed with the aid of the design equations shown below. The components should be high quality, stable devices; such as, mica or polystyrene capacitors, and metal film or deposited carbon resistors.

$$\text{Attenuation} = \frac{R_1}{|Z|}$$

$$\text{Phase Shift} = \text{Tan}^{-1}\ \frac{R_2}{X_C}$$

Providing $R_1 \angle \angle |Z|$



$$Z = \frac{R_2}{1+j\ \frac{R_2}{X_C}}$$

$$|Z| = \frac{R_2 X_C \sqrt{X_C^2+R_2^2}}{X_C^2 + R_2^2}$$

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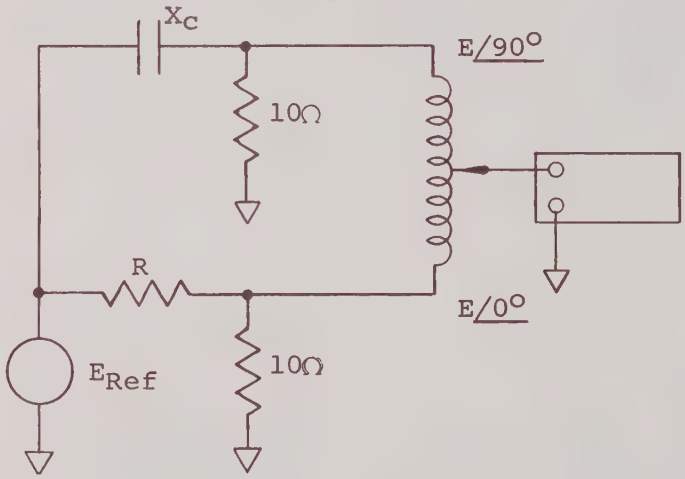
Ratio Box Phase Shifter - This circuit is somewhat less complicated than the previous circuit in that it requires only a precise 0° and 90° signal be generated by use of passive networks but it does require that a high quality Ratio Box which is accurate at the operating frequency be used. The components again must be high quality and drift free. It may be seen that any angle between 0° and 90° can be selected depending on the setting of the Ratio Box. It should be noted, however, that the amplitude of the 0° and 90° signal should be set equal to each other. The output amplitude will vary through a minimum of 0.707 of the 0° and 90° signals at 45° (Ratio Box setting of 0.5).

Phase network component values and Ratio Box settings are determined by the equations shown.



$$\frac{X_C}{10} >> 1000$$

$$R = X_C$$

$E/0^{\circ}$ and $E/90^{\circ}$ must be set equal within 1/4%.

Ratio Box setting = $\frac{1}{1+\text{ctn}\theta}$ where θ is desired phase shift.

Resolver Simulator Phase Shifter - The third system is that of the resolver simulator phase shifter. This circuit very closely simulates the performance of the resolver in that the phase angle generated is between 0° and 90° at a constant amplitude. The same passive networks as above are used to generate the 0° and 90° and also as above their amplitudes must be set equal to each other. Two Ratio Boxes are used to drive a bridging transformer. The 0° and 90° signals of varying amplitudes as set by the Ratio

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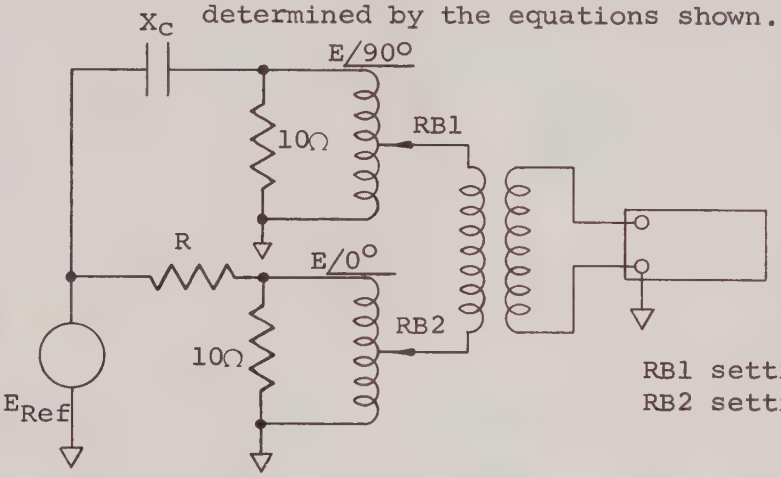
Boxes are then summed vectorally in the bridging transformer and the resultant output is fed to the Model 301A. Phase network component values and Ratio Box settings are determined by the equations shown.



$\frac{X_C}{10} >> 1000$

$R = X_C$

E/0° and E/90° must be set equal within 1/4%.

RB1 setting = sin θ
RB2 setting = cos θ
} where θ is desired phase shift.

NAI Model 350/351 Phase Generator - Phase Calibrator

The Model 350 Phase Generator uses the same technique as the latter, above-mentioned system packages in one convenient instrument. Front panel controls, calibration in phase angle permit direct selection of phase angles, avoiding the necessity for computing component values and ratio box settings. The frequency range of the instrument is 50Hz to 25.6KHz

The Model 351 Phase Calibrator provides a means for precise calibration and extends the output voltage and drive capability of the 350 Phase Generator.

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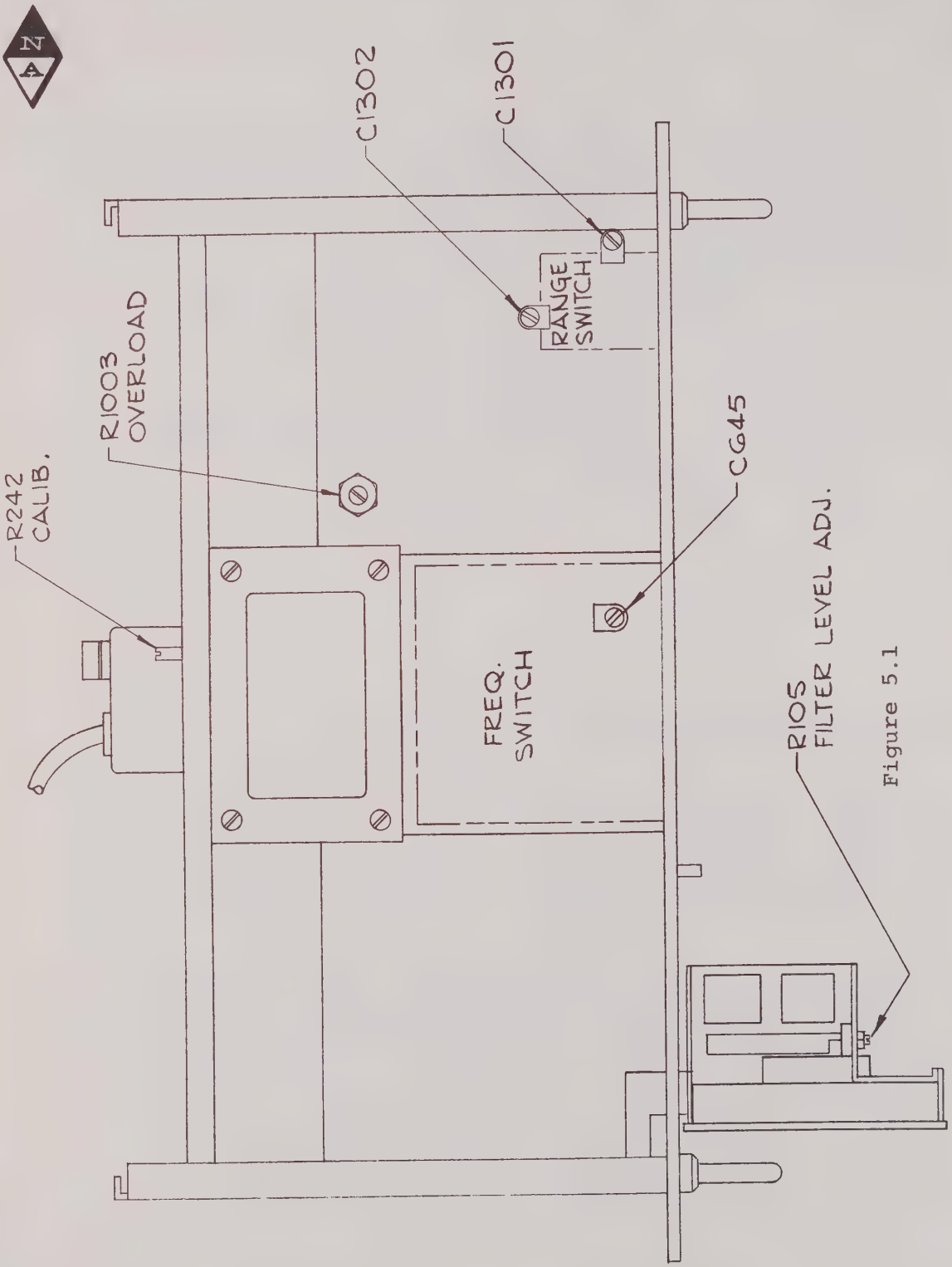
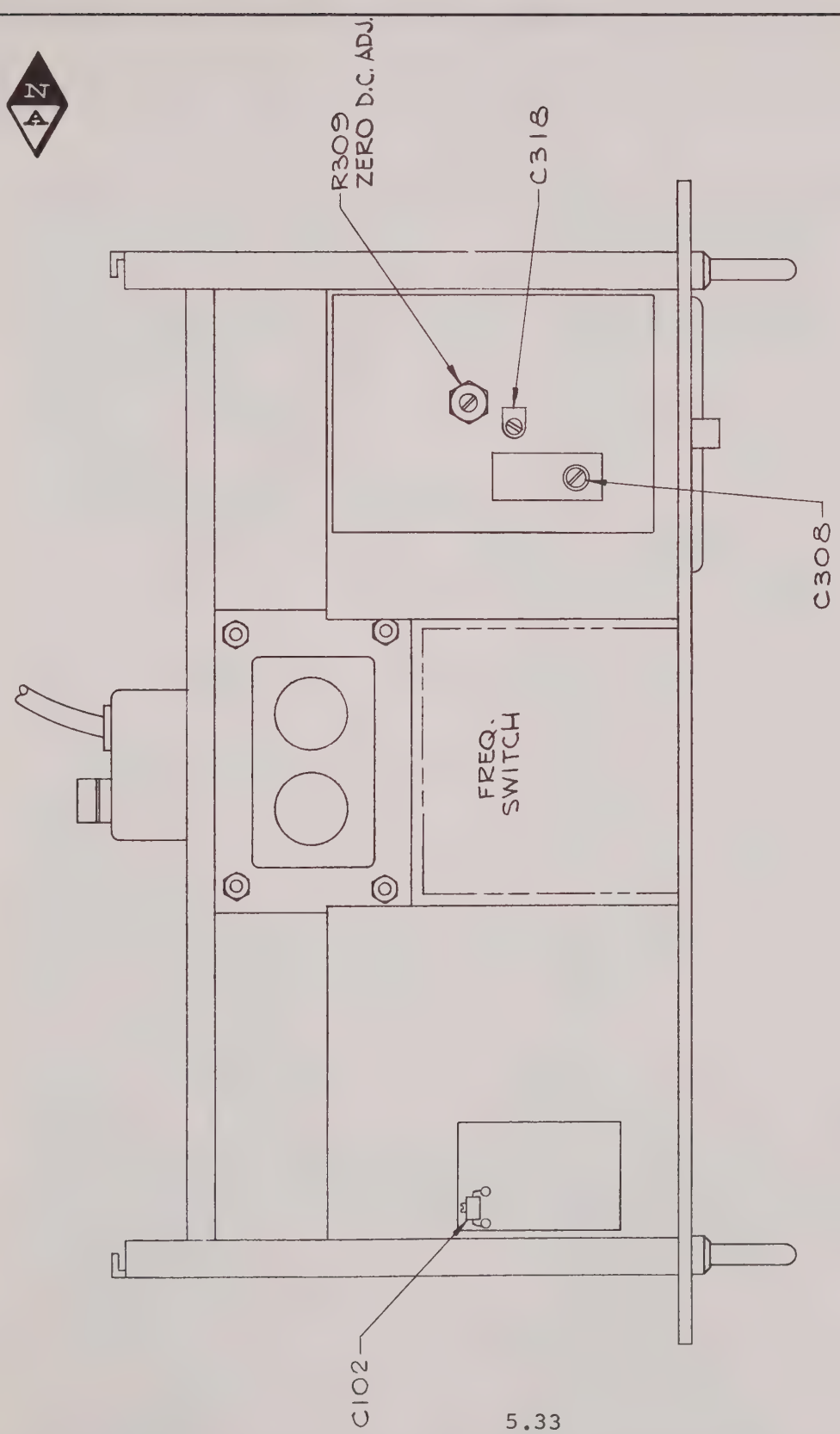

C1302
C1301
RANGE SWITCH
R1003 OVERLOAD
R242 CALIB.
C645
FREQ. SWITCH
R105 FILTER LEVEL ADJ.
TOP VIEW

Figure 5.1



BOTTOM VIEW

Figure 5.2

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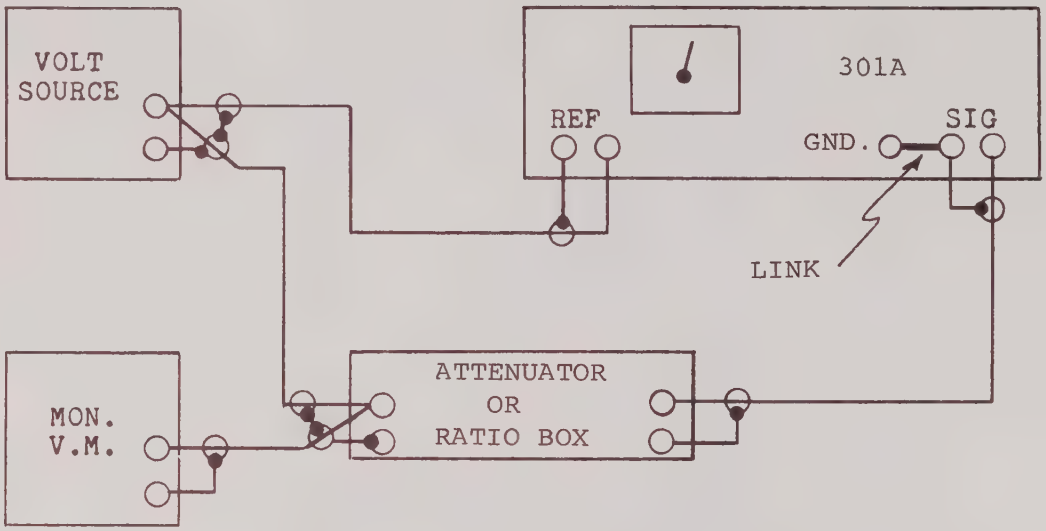

Figure 5.3A

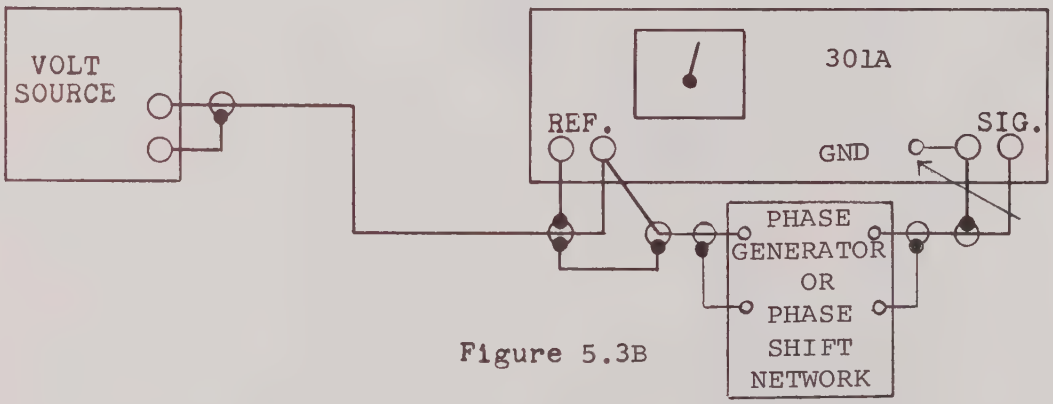

Figure 5.3B

NOTE: All test equipment grounds must be connected to 301A ground. The 301A ground is connected to House Ground by means of the shorting link. This requires that all test equipment line cord or chassis grounds are not connected to house ground.

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A. North Atlantic Industries, Inc. warrants the Product(s) against defects in material and workmanship for one year from the date of original shipment. The Seller's liability is limited to the repair or replacement of the Product(s) which proves to be defective during the Warranty period.

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APPLICATION NOTES

FOR

SERIES 200

PHASE ANGLE VOLTMETERS

The North Atlantic Industries Series 200 Phase Angle Voltmeter is a truly unique, multifunctional instrument which will function as a sensitive voltmeter, a phase angle meter, a meter measuring in-phase signals (E cos θ), and quadrature signals (E sin θ), a phase sensitive null indicator, an impedance meter, and a power factor meter.

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TABLE OF CONTENTS

		Page
I.	Introduction	1
II.	General Notes on Grounding Techniques	2
III.	Phase Characteristic	6
	1. Response to Harmonics	
	2. Accurate Phase Measurements	
IV.	Phase Angle Measurement Using Phase Shifter	11
V.	Measurement of In-Phase and Quadrature Components	12
VI.	Measurement of Power Factor and Impedance Angle	12
VII.	Measurement of Impedance	13
VIII.	Applications	15
	1. Precision Ratiometer	15
	2. Transducer Nulling	16
	3. Synchro Bridge Null Detector	17
	4. Magnetic Amplifier and Thyratron Circuit Alignment	18
	5. Carrier Circuits and Amplifier	18
	6. Transformation Ratio	19
	7. Small Angle Measurements	22

I - INTRODUCTION

The following notes will acquaint the user of the 200 Series Phase Angle Voltmeter with the many ways in which these versatile instruments can be used.

By virtue of the instrument's ability to measure the two basic characteristics of any signal; namely, magnitude and phase angle, measurements are now possible which previously either required extensive associated equipment or could not be made at all.

The principle of operation is illustrated in Figure (1).

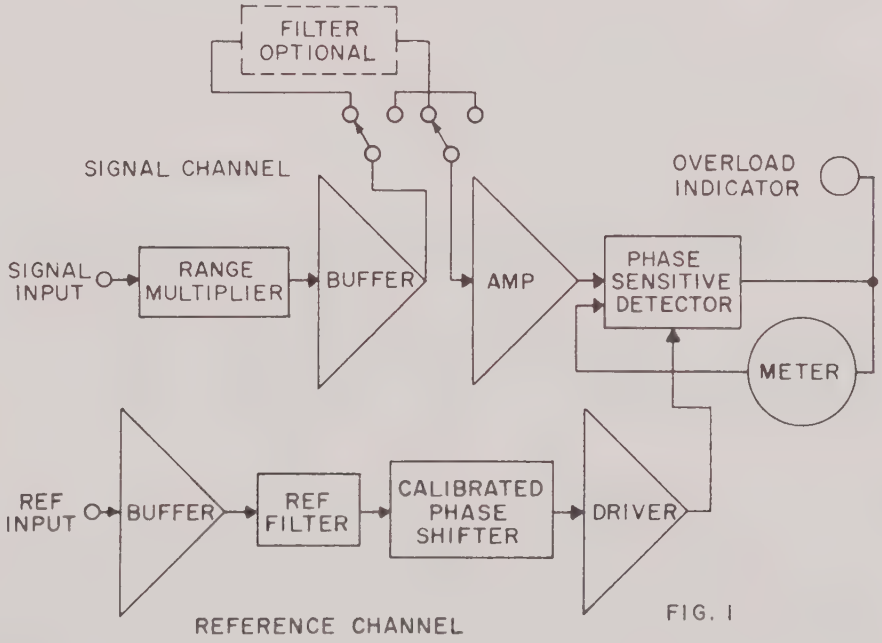

FIG. 1

An input signal is first attenuated by the range multiplier. The high gain amplifier drives a phase sensitive detector which in turn drives the indicating meter. The meter output is recombined to form an AC signal which is fed back to the amplifier input thus making the instrument independent of diode characteristics and tube ageing. A reference signal is also amplified and its phase angle shifted by the calibrated phase shifter. This signal driving the phase sensitive detector results in the phase angle characteristics shown in Figures (5) and (6).

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The sections to follow describe the many ways in which this instrument is being used. Block diagrams illustrate typical measuring set ups.

II - GENERAL NOTES ON GROUNDING TECHNIQUES

Successful measurement with any high input impedance voltmeter is dependent upon the elimination of all unwanted or extraneous signals from the measurement circuit.

The most common sources for extraneous signals are the following:

a) Internal noise
b) Electrostatic pickup
c) Inductive pickup
d) Common ground runs

Internal noise has been minimized by design and is equivalent to less than 5 microvolts for a high impedance circuit (1.0 megohm).

Electrostatic pickup, frequency a problem in high impedance circuits, is easily eliminated by shielded cable or twisting leads one of which is at ground potential. Care must be taken, however, to avoid loading the signal source by the cable capacitance.

Inductive pickup is generally less often encountered than electrostatic pickup and possibly for that reason, methods for minimizing it are not frequently employed. Both twisted and shielded leads are effective in reducing this form of pickup because they minimize the effective area through which extraneous electromagnetic flux can pass. This is true in the case of a shielded lead, only if the shield, for example, is the return circuit for the signal.

Inductive pickup in ground leads can and does occur with multiple point grounding systems. The effect of these ground loops frequently can be reduced by bundling cables together, again so as to minimize loop areas. A better method is to eliminate the ground loops altogether especially those in the signal system or that

portion of a circuit where a measurement is being made. Figure (2) shows several workable methods for using the voltmeter as a phase sensitive null detector when making transformation measurements. All methods can be made to work by minimizing stray fields and bundling cables together. However, Figure (2A) is the most advantageous arrangement and is not at all critical to lead runs. Figures (2B) and (2C) both have loops which can be potential trouble spots. Note also that grounds other than those shown in Figure (2) can exist due to chassis contact, line cord ground, and reference grounds. All must be considered when setting up the measuring system.

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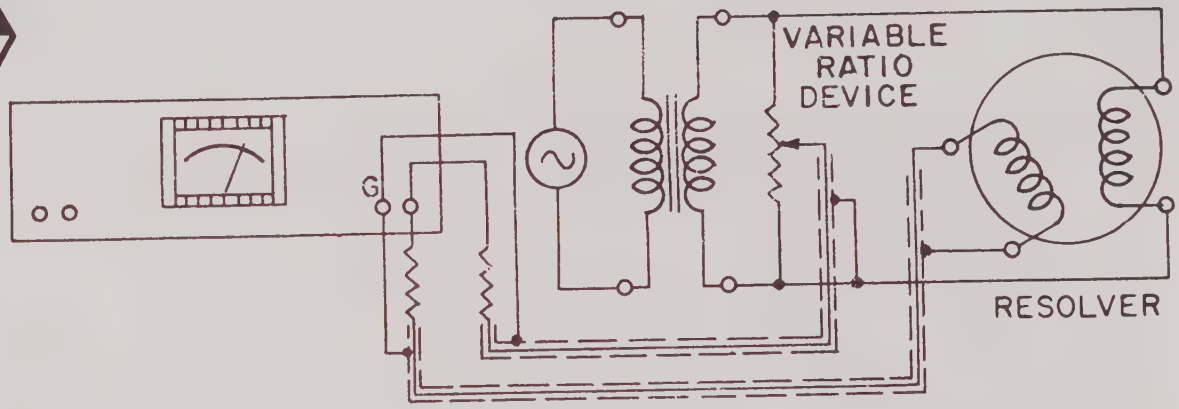
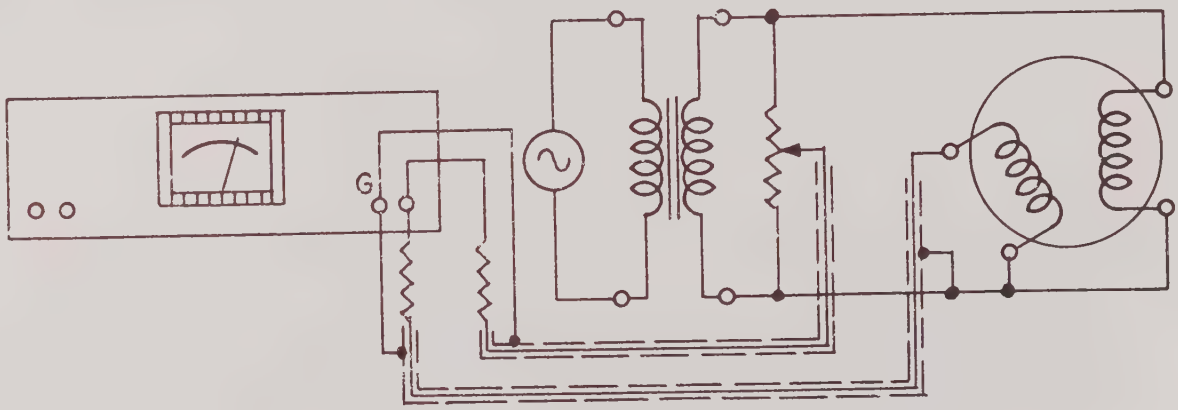
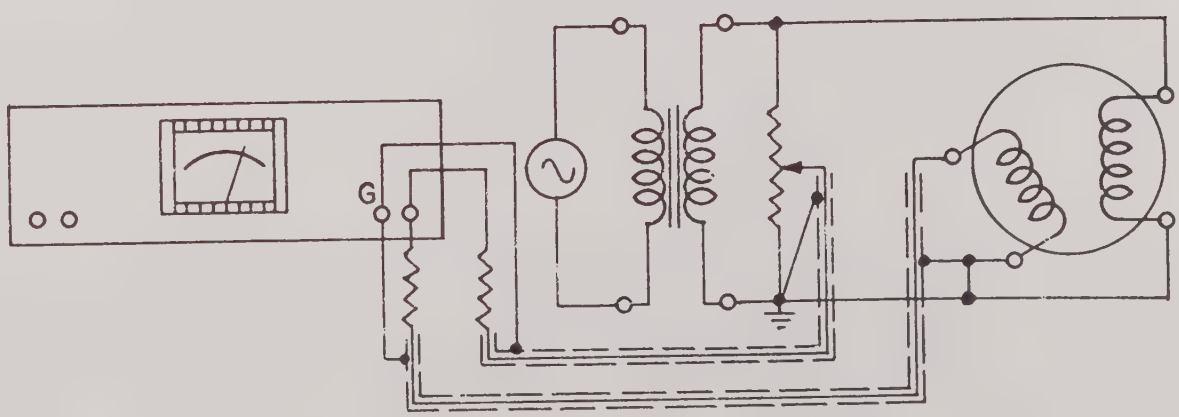


(a)—GOOD, NO LOOPS



(b)—ONE LOOP, PICK-UP POSSIBLE



(c)—POOR—ONE SIGNAL LOOP AND ONE GROUND LOOP

FIG. 2—RATIOMETER WITH SERIES SUMMING

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Common ground runs are sources of extraneous signals by virtue of voltage drops in the voltmeter input which arise from ground current other than the signal ground current. Figure (3) is a sketch of a typical arrangement wherein the power ground lead is in part that of the shield on the signal input. A portion of the load current as well as power supply leakage current to ground go through the voltmeter input cable. The voltage drop in the length of common ground is measured in addition to the signal.

Figure (3) also illustrates the internal grounding arrangement. The fact that there are four places in which a ground can be made could mean that isolation transformers are required somewhere in the measuring circuit.

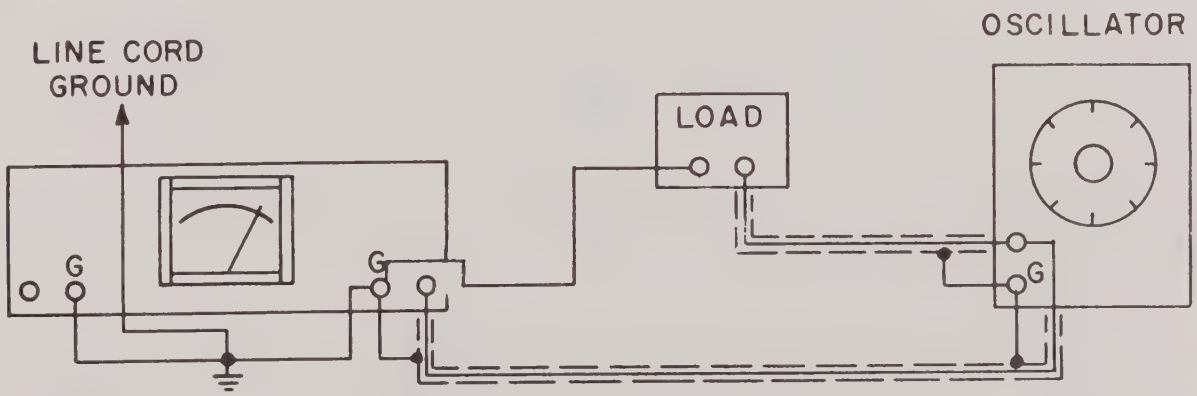

FIG. 3

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III - PHASE CHARACTERISTIC

The response of the Phase Angle Voltmeter to the fundamental frequency is given by:

(1) $E_{meter} = E_{rms} \times \cos \theta$

where E_{meter} = voltage read on the meter
E_{rms} = rms value of the input sine wave
θ = angle between the reference and signal input (Phase shifter at zero degrees)

Response to even order harmonics is theoretically zero, while odd harmonic response varies inversely with the order of the harmonic.

For example, for the 3rd harmonic equation (1) becomes:

(2) $$E_{meter} = \frac{E_{rms\ (3rd\ harmonic)} \times \cos \theta'}{3}$$

where θ' is the phase angle of the 3rd harmonic with respect to the reference.

Actually response to harmonics departs from equation (2) for a number of reasons. Since calibration of the instrument is at the fundamental frequency, measurements at frequencies other than the fundamental frequency will be somewhat in error.

For instruments having selective filters in the signal and reference channels, harmonic response will in all cases be more than 55DB down. Table I shows typical measured responses. The values shown with filters actually are the sum of the colum I data and the filter characteristic.

TABLE I

FUND (400cps)	No Signal Filter 0DB	With Signal Filter 0DB
2nd Har.	-55DB	-55DB
3rd Har.	-9.5DB	-55DB
4th Har.	-55DB	-55DB
5th Har.	-14DB	-55DB

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Measurements of phase angle using equation (1) are easily accomplished with good accuracy using the setup dhown in Figure (4). The actual phase characteristic used in the measurement is E sin θ for purpose of convenience. The procedure is to adjust accurately the θ = 90 deg. and the θ = 0 deg. point. Measurement than will be a voltage which can be directly translated into degrees using the curves of Figures (5) and (6).

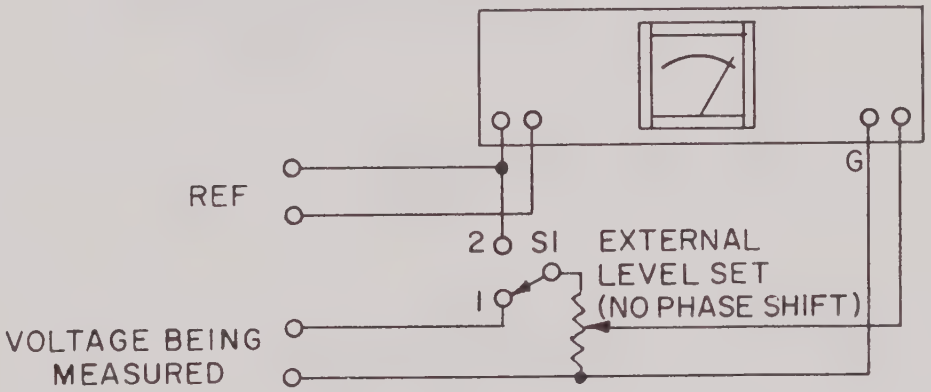

FIG. 4

The step-by-step procedure is:

1. Set reference level to red line value.

2. With meter in "STD VTVM" position and external switch S1 in position 1, select a convenient range and adjust the signal level for full scale deflection. This will insure on-scale readings. (NOTE: Any external level set should be sufficiently low in resistance so as not to introduce phase shift error.)

3. Next switch the reference into the signal channel by switching S1 to position 2 and adjust using the same external level control for full scale deflection.

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Switch the instrument to the "PHASE ANGLE VTVM" function and adjust the phase shift dial for zero meter reading. This establishes the θ = 0 deg. point or quadrature null point.

NOTE: FOR MAXIMUM ACCURACY, THIS POINT SHOULD BE RESET WHENEVER THE SCALE IS CHANGED.

4. Return the switch S1 to the signal input and readjust the full scale level with the instrument set as "STD VTVM". This establishes the θ = 90 deg. point (E maximum).

5. Switch back to the "PHASE ANGLE VTVM" position used in (3) above and read the meter. Enter the curves of Figure (5) or (6) to read degrees.

Any full scale range in degrees can be used even down to -6 deg. - 0 - +6 deg, depending upon the full scale limits. For example, if the full scale 90 degree point is set on the 1.0 volt scale and the zero point on the 3.0 volt scale, then the 3.0 volt scale will cover a range of from -17.4deg. - 0 - +17.4 deg. Table II summarizes typical setups and Figures (5) and (6) show curves which can easily be used to convert voltage measurements to degrees. These curves are actually arcsin functions. The angle can also be derived by direct computation from the voltage readings.

Errors in using this type of measurement will be a function of the scale used and the angle. In addition, for large ratios of maximum voltage to full scale values being used, saturation for a portion of each cycle can occur and will result in a small scale error. Obviously, this condition is a function of reference level and for that reason, a level of twice the red line value is recommended when using this technique.

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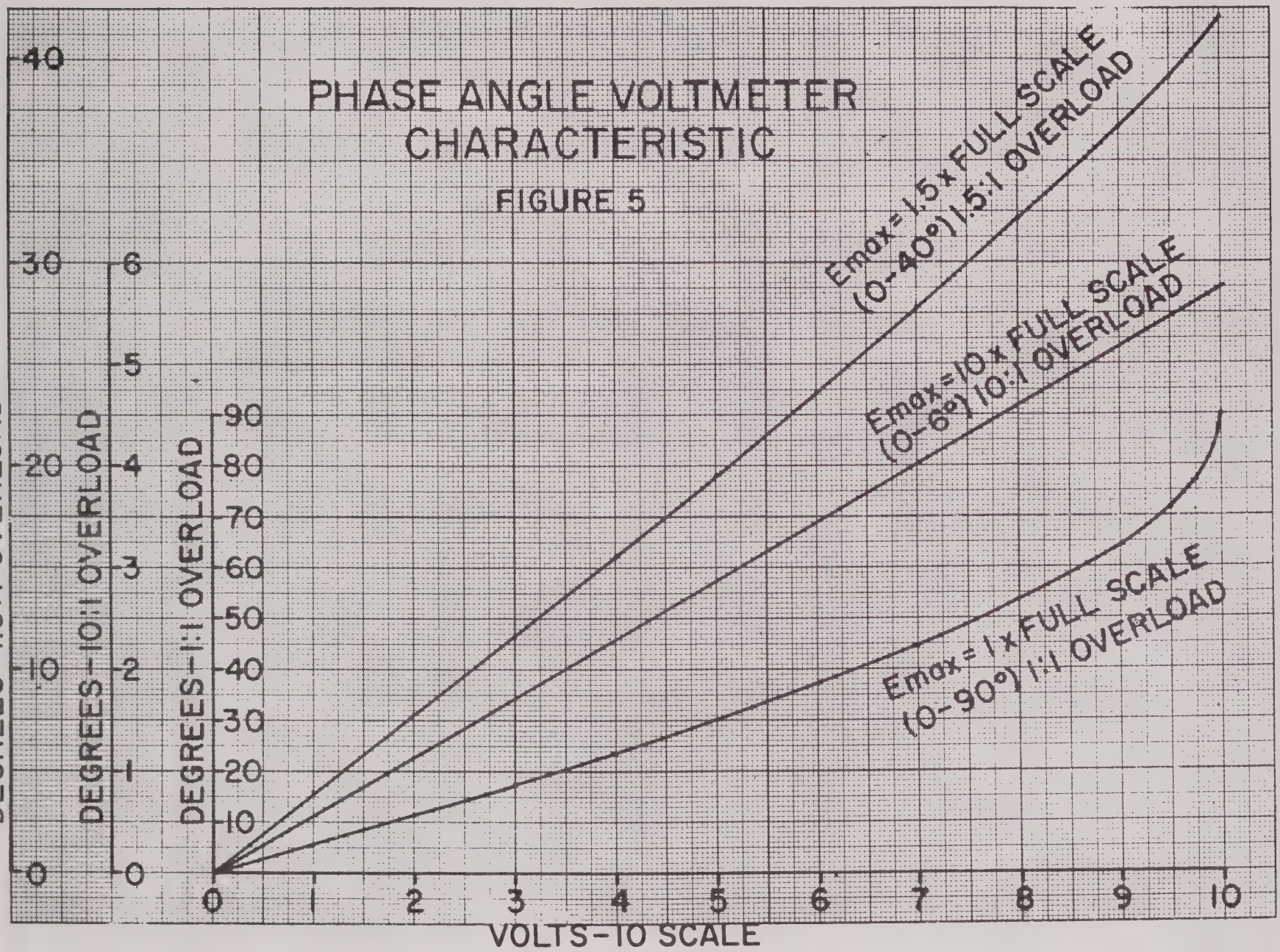
PHASE ANGLE VOLTMETER
CHARACTERISTIC
FIGURE 5
Emax=1.5x FULL SCALE
(0-40°) 1.5:1 OVERLOAD
Emax=10x FULL SCALE
(0-6°) 10:1 OVERLOAD
Emax=1x FULL SCALE
(0-90°) 1:1 OVERLOAD
DEGREES-1.5:1 OVERLOAD
DEGREES-10:1 OVERLOAD
DEGREES-1:1 OVERLOAD
VOLTS-10 SCALE
0
10
20
30
40
1
2
3
4
5
6
7
8
9
10
60
50
70
80
90

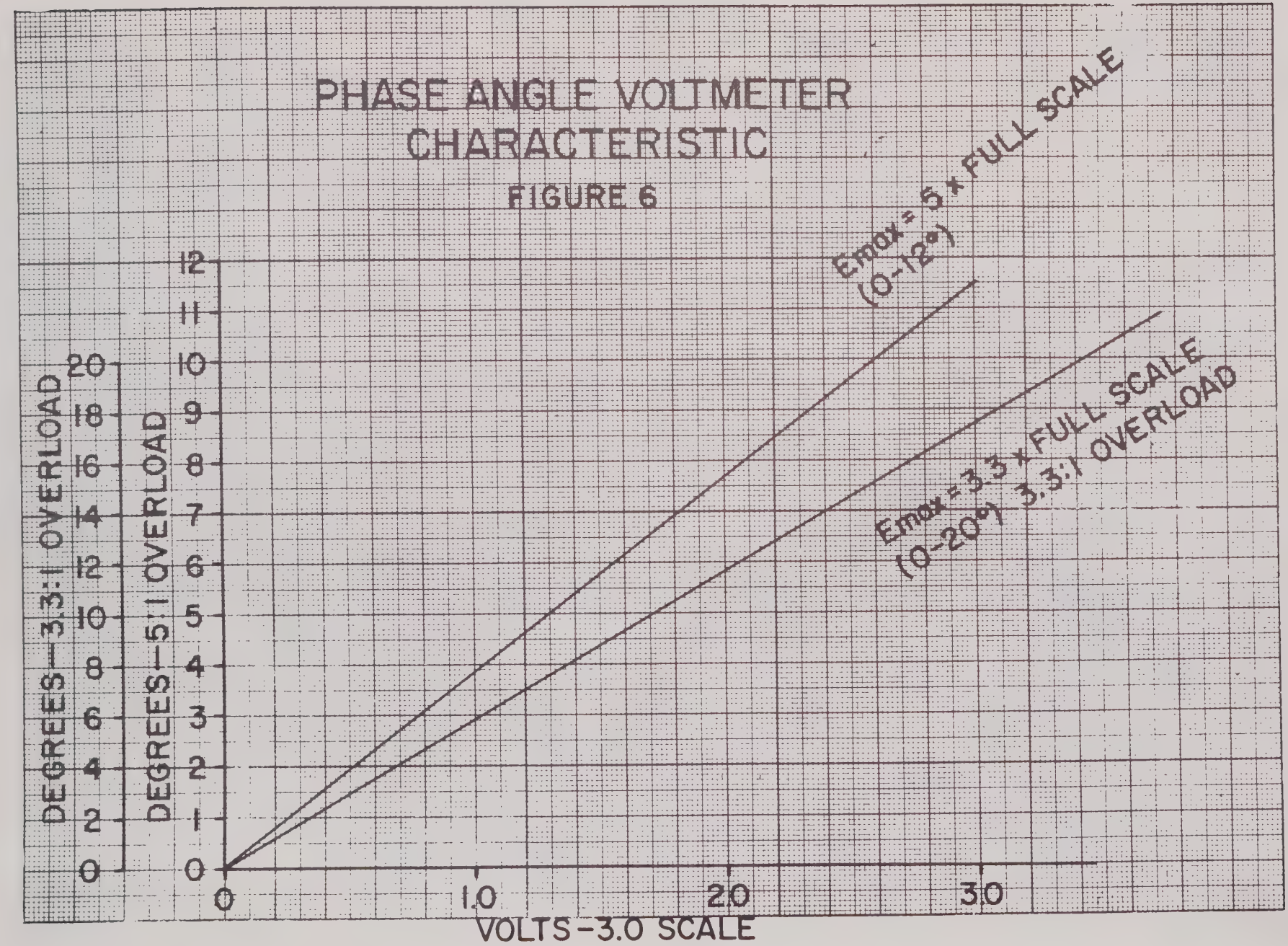
PHASE ANGLE VOLTMETER
CHARACTERISTIC
FIGURE 6
Emax = 5 x FULL SCALE
(0-12°)
Emax = 3.3 x FULL SCALE
(0-20°) 3.3:1 OVERLOAD
DEGREES—3.3:1 OVERLOAD
DEGREES—5:1 OVERLOAD
0
2
4
6
8
10
12
16
18
20
0
1
2
3
4
5
6
7
8
9
10
11
12
0
1.0
2.0
3.0
VOLTS—3.0 SCALE

TABLE II

Maximum Voltage	Scale for Measuring Degrees	Full Scale Overload Ratio	Degree Range	Max. Error 3%	Figure
1.0	1.0	1:1	90	2.7 deg.	5
1.0	.3	3.3:1	19.5	0.6	6
1.0	.1	10:1*	5.7	.2*	5
1.5	1.0	1.5:1	41.8	1.3	5
1.5	.3	5:1	11.5	.33	6

*NOTE: The overload alarm will be lighted when operated under these conditions. Saturation errors exist and for that reason no error rating is made.

High accuracy Phase Angle Measurements to better than .01° can be made using the alternate methods discussed in Section VIII under Small Angle Measurements.

IV - PHASE ANGLE MEASUREMENTS USING CALIBRATED PHASE SHIFTER

The built-in, calibrated phase shifter can be used to measure phase angle directly simply by shifting the reference by an amount equal to the phase angle being measured so as to produce a maximum meter reading in accordance with equation (1). Precise determination of the maximum point is difficult due to the zero slope of the phase characteristic at $\theta = 0$ deg. To avoid this difficulty, the instrument is equipped with four scales 90 degrees apart. Thus, by simply switching the reference 90 degrees, the phase shifter dial can be readily set to a zero point on the meter and then by switching back to the original quadrant the unknown phase angle can be read.

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This procedure allows the measurement of phase angles from 0 to 360 degrees. Ambiguity which exists for two quadrants is easily removed by adding 180 degrees to the dial reading if a negative maximum (meter deflection to the LEFT) is used for the measurement. For positive maximums (meter deflections to the RIGHT) the dial scales apply directly.

V - MEASUREMENT OF QUADRATURE AND IN-PHASE COMPONENTS OF A SIGNAL

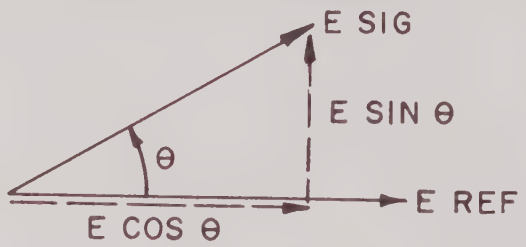

FIG. 7

The quadrature and in-phase components of a signal are defined in accordance with the diagram of Figure (7) as:

In-phase component = E cos θ

Quadrature component = E sin θ

Measurement of the in-phase component is made by placing the Phase Angle Dial at zero degrees and reading the meter directly. This voltage will be E cos θ. (Function Selector must be in one of the PHASE ANGLE VTVM positions). By switching the Function Selector to an adjacent quadrant, the reference is shifted 90 degrees and the meter now reads the quadrature component of voltage E sin θ. For the greatest accuracy in this type of measurement, the null or 90 degree point should be calibrated on the scale in which the voltage component is to be read. See the section under PHASE CHARACTERISTIC for a description of this type of adjustment.

VI - MEASUREMENT OF POWER FACTOR AND IMPEDANCE ANGLE

Both power factor and impedance angle are defined as the angle which a current vector makes with the voltage reference. This

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measurement is conveniently accomplished by means of the set up shown in Figure (8). The angle is measured as previously discussed.

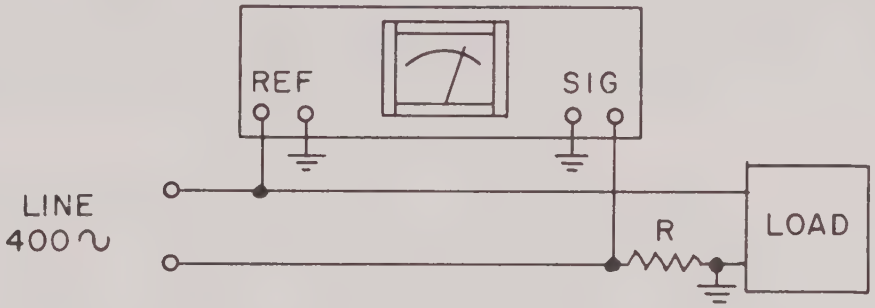

FIG. 8

VII - IMPEDANCE MAGNITUDE

The magnitude of any impedance is measured by using the "STD VTVM" portion of the instrument. Figure (9) illustrates the manner in which the measurements can be made.

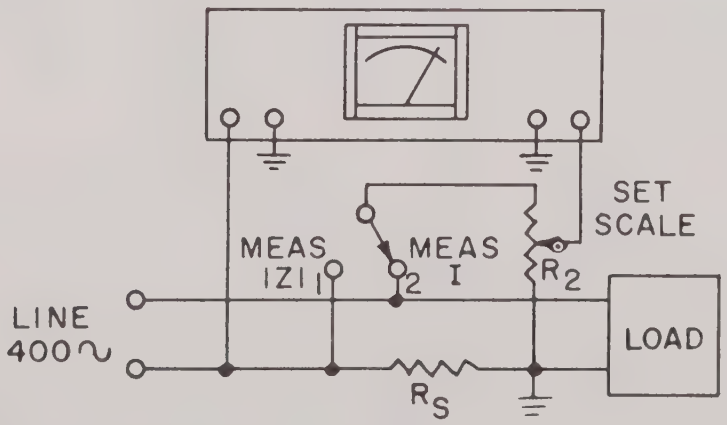

FIG. 9

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Using Table III as a guide, a precision ($\pm$ 1%) resistor of convenient size is selected for Rs. With S1 in position 1 for measuring current, adjust the scale set potentiometer to read full scale voltage on any 10 scale. Note the actual voltage value. Switch S1 to position 2 for measuring /Z/ and read the meter. This reading will be the impedance magnitude expressed in units of kilohms, ohms, hundreds of ohms, milliohms, etc. depending upon the value of Rs series resistance used per Table III and when divided by the current measurement noted above.

EXAMPLE:

Load impedance = 470K
Rs = 1K
E line = 115 volts

With S1 in position 1 set the level using R2 to a convenient full scale of 10. This might be 0.1 volts. Switching then to position S2 will produce a meter deflection of 47K on the 100K scale (100 volts scale is now 100K per Table III). Dividing this by the current scale of 0.1 will yield 470K. Since the current factor is always set at a multiple of 10, this last correction is simple to accomplish.

TABLE III

Series Resistor	Scale 1V equals	Current Factor
10K	10K	1/volts
1K	1K	1/volts
100Ω	100Ω	1/volts
10Ω	10Ω	1/volts
1Ω	1Ω	1/volts

Measurement of AC Resistance and Reactance

By using the circuit of Figure (9) the real and imaginary components of the impedance can also be measured directly by using the current as a reference and measuring the in-phase and quadrature of the signal measured with the switch in position 2. The in-phase component will be the AC Resistance and the quadrature component will be the reactance with the sign determined as positive for a

right hand meter deflection and negative for a left hand deflection.

The following series of block diagrams will illustrate how this instrument can be applied to some of the specific applications noted earlier.

VIII - APPLICATIONS

Precision Ratiometer

In many analog computer systems the process of multiplication, division, addition, and subtraction is accomplished using precision potentiometers, or resistors. Those applications involving extremes of precision must be concerned with the distributed capacitance of the circuit element. Ordinary nulling system, for example, will not permit the manufacture of very precise resistors because of the errors masked by quadrature signals. The circuit of Figure (10) permits precise zeroing of pots or matching and calibration of resistors and potentiometers independent of stray capacitances, or harmonics in the signal source.

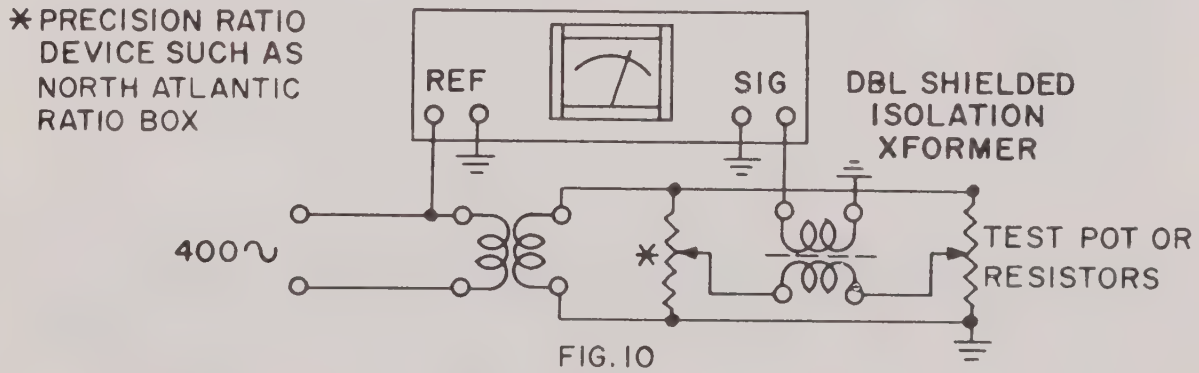

FIG. 10

Two isolation transformers are actually not necessary. If the source is to be isolated then an inexpensive transformer can be used. If the outputs are to be isolated then a low capacitance

transformer such as North Atlantic's T-110 should be used. An alternate arrangement would be the circuit of Figure 11, which uses a summing network.

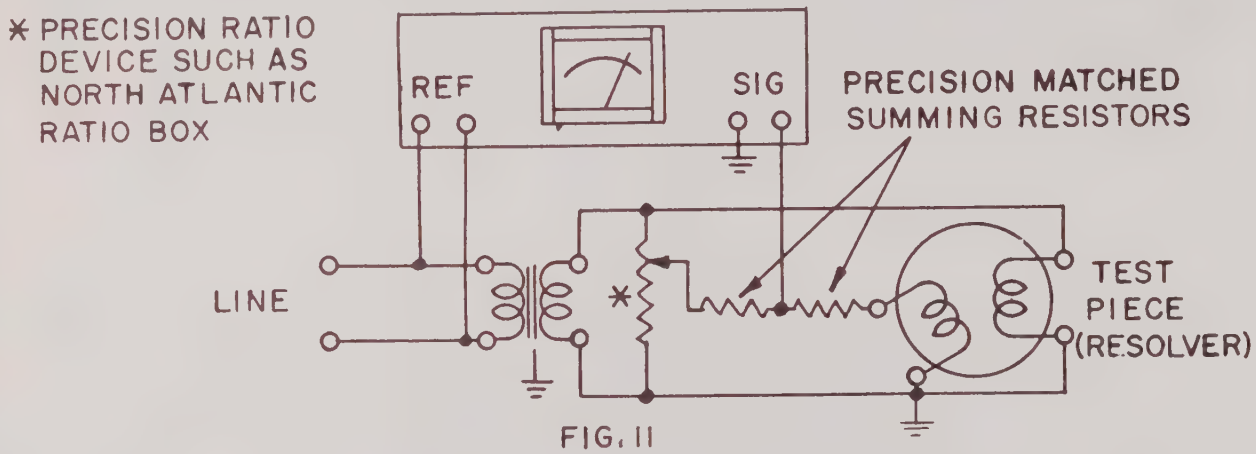

FIG. 11

Transducer Nulling

Applications involving transducers, such as differential transformers or E-Coil pickoffs, are extremely difficult to zero due to the large residual null voltage composed of signal and harmonics from the source as well as harmonics generated in the transducer. Figure (12) shows a system in which a precise in-phase balance can be achieved in the presence of quadrature and harmonics equal to 10 times the full scale sensitivity used. An order greater accuracy in nulling is easily achieved over conventional nulling circuits.

In addition, phase compensation for servo systems or for purposes of linearity compensation are easily accomplished using variations of this same test set-up.

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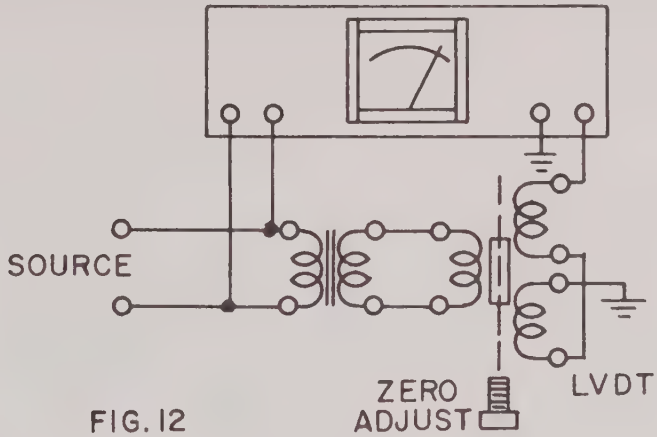

FIG. 12

Synchro Bridge Null Detector

When measuring the electrical errors of synchros, a circuit such as that shown in Figure (13) is used. The phase sensitive characteristics of the Phase Angle Voltmeter as well as the harmonic rejection of the filters and detector makes possible nulls obtainable by conventional instrumentation.

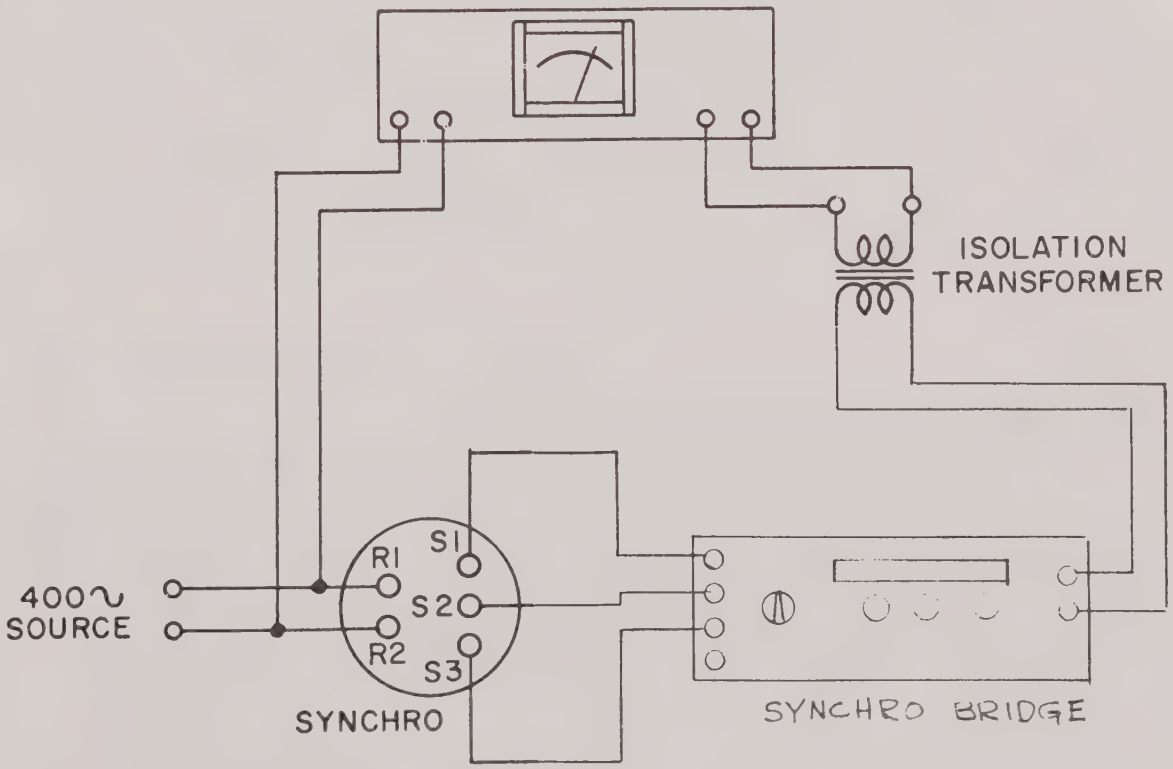

FIG. 13

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Magnetic Amplifier and Thyratron Circuit Alignment

Circuits using thyratron power stages or magnetic amplifier stages cannot be monitored using conventional instruments because measurement errors can be prohibitively large due to the chopped waveforms. If the Phase Angle Voltmeter is used to monitor the output of such devices as shown in Figure (14) the task of alignment for maximum torque or output is straightforward since the meter reading is equivalent to motor output.

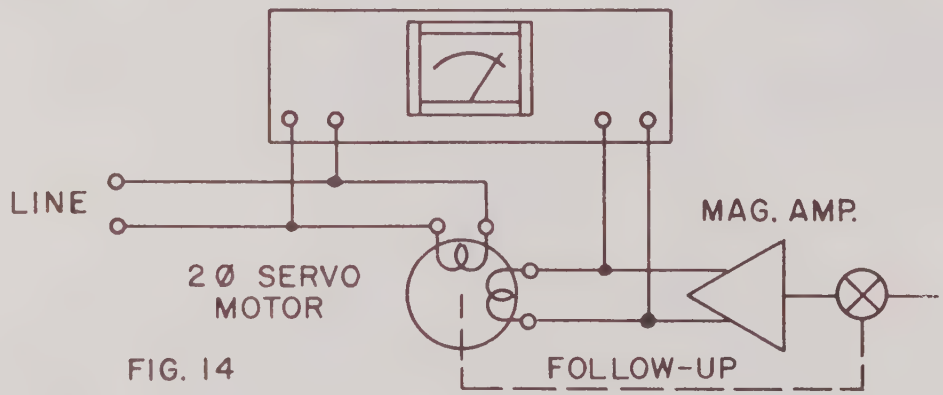

FIG. 14

Carrier Circuits and Amplifiers

Circuits such as those used for phase compensation, summing circuits, amplifiers, etc., must frequently be aligned to reduce quadrature effect to an acceptable minimum and to establish transfer functions at precise values of Phase Angles. Figure (15) is a test setup used to check the phase angle transfer characteristic of a 400 cps carrier amplifier. Switch, S1, is used to adjust exactly the 90 degree point. A precision of trim to a fraction of a degree can be obtained.

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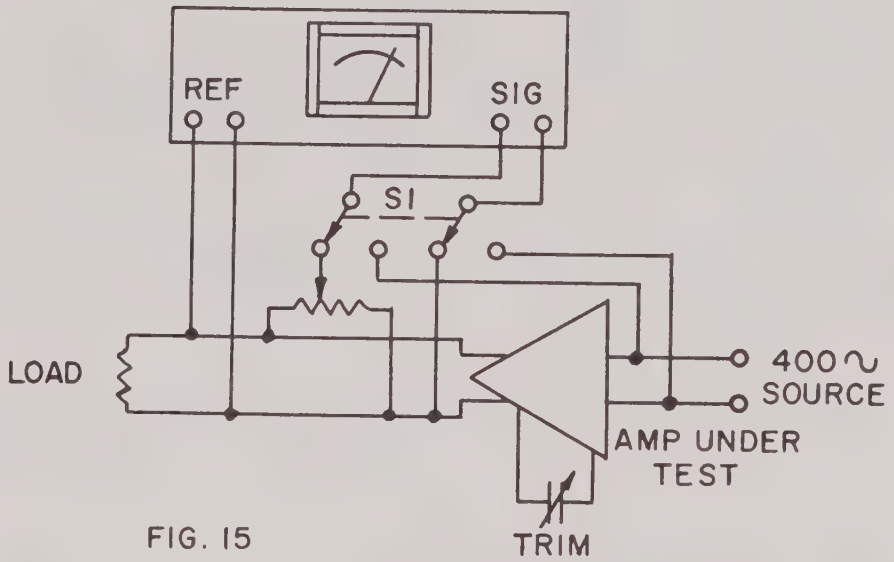

FIG. 15

Transformation Ratio

Numerous circuit arrangements are used in making transformation ratio measurements. Two of the most practical are shown in Figure (16a) and (16b).

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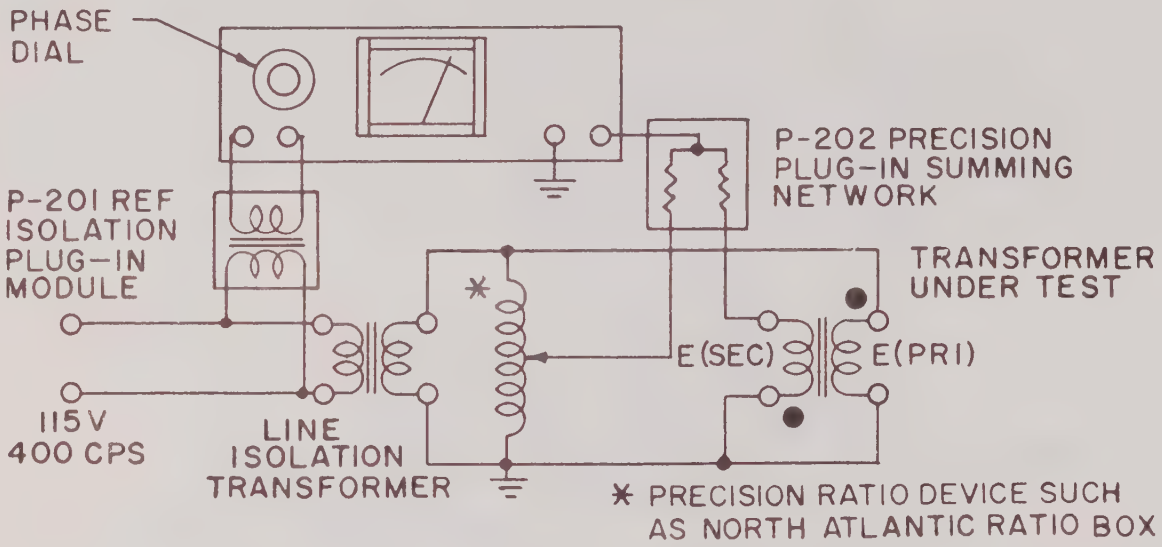

FIGURE 16(a)

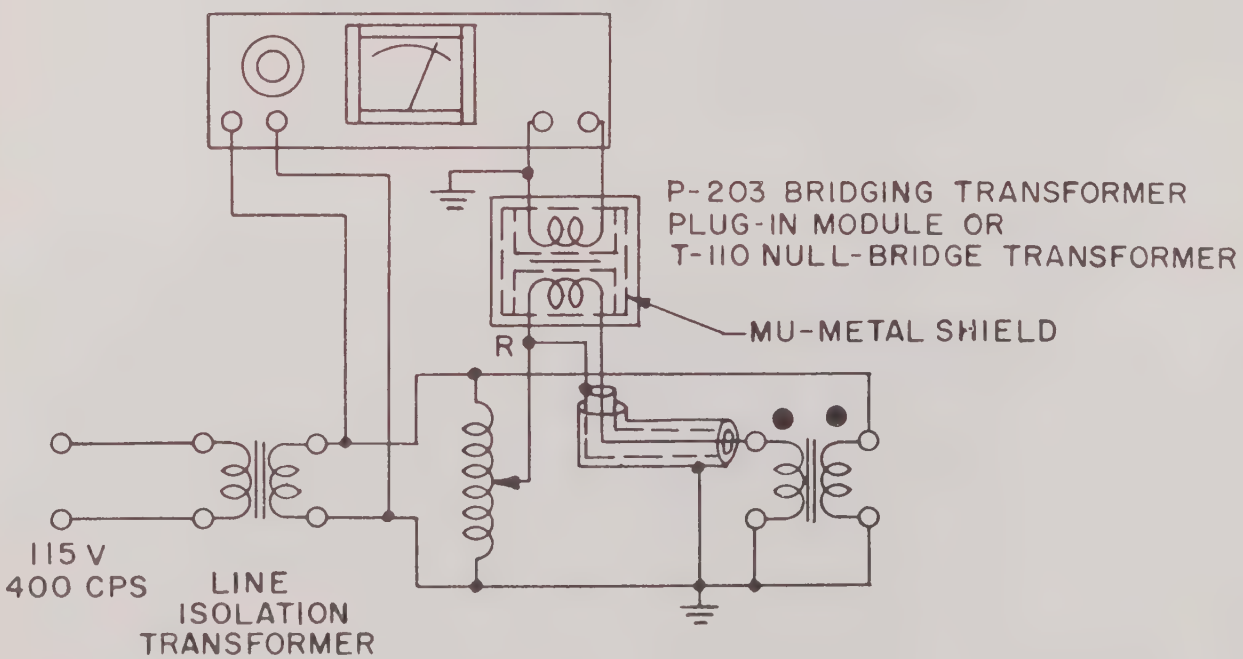

FIGURE 16(b)

I. SUMMING NETWORK TECHNIQUES

In Figure (16a) the output of the test piece is arranged to have a polarity opposite to that of the ratio device. By means of precision summing resistors - available from NORTH ATLANTIC as the P202 PLUG-IN SUMMARY MODULES, the outputs are added. At null the ratio device will then read the in-phase ratio of the item under test. In this particular test setup a line isolation transformer is utilized so as to avoid grounding one side of theline. For illustrative purposes the NORTH ATLANTIC P-201 PLUG-IN REFERENCE ISOLATION MODULE is also shown as providing circuit isolation on the reference input. This feature can also be built into the voltmeter.

In using the circuit of Figure (16a) care should be exercised in evaluating the errors which can arise due to loading of the test piece by the summing resistors and inaccurate summing due to test piece source impedance.

Phase angle is easily measured using the technique shown in the following section for small angle measurement. Allowance must be made in this case for the 2:1 change in voltmeter sensitivity resulting from the summing network.

II. BRIDGING TRANSFORMER TECHNIQUE

For greater accuracy, the circuit of Figure (16b) has found wide acceptance where the requisite polarity arrangement is feasible. In this case, matching of the test piece output to the ratio device is achieved by using a bridging transformer. A NORTH ATLANTIC P203 BRIDGING TRANSFORMER MODULE is shown, although any good double-shielded isolation transformer with suitable common-mode rejection and low input capacitance would suffice.

Measurement errors in Figure (16b) can occur due to capacitive loading of the test piece or capacitive coupling of the common mode signal into the secondary. The former can be minimized where shielded cables are used by using the so called "driven shield" technique shown in the Figure.

Common-mode rejection is a function of the transformer shielding, the impedance level of each input to the transformer and the relative values of these impedances. Each setup must be judged by itself as to its suitability for a particular measurement.

Phase angle again is easily measured using the small angle measuring technique shown in the following section. Here allowance must be made for the bridging transformer transformation ratio (1:1 for the NORTH ATLANTIC P203 MODULE).

Both of the above measuring systems are used to provide a direct reading of in-phase ratio. Transformation ratio is by definition the ratio of the absolute magnitude of the secondary to primary voltage. To obtain "transformation ratio" the "in-phase" ratio must be divided by the cosine of the phase shift angle.

Maximum accuracies for both setups require that the Phase Dial be adjusted to compensate for residual phase shifts arising from the various transformers in the system, etc., This is conveniently done by stepping the ratio device and adjusting the Phase Dial to produce zero output when the Function Selector is in the 90^{o} position. Operation will then be correct when the Function Selector is returned to the 0^{o} position.

Small Angle Measurements

Small angle measurements to better than $.01^{o}$ can also be made using the setups of Figure (16). The process consists of making the in-phase null, described in the foreoing, using the precision ratio device. Then, by definition the phase shift angle α is:

$$\alpha = \text{Tan}^{-1} \frac{\text{E Input (quadrature)}}{|\text{E sec}|} = \text{Tan}^{-1} \frac{\text{E Input (quadrature)}}{|\text{E pri}| \times \text{Ratio}}$$

By measuring the magnitude of the secondary voltage and the quadrature component of the input signal, the angle α can be determined.

For Example:

Measured quadrature = 30.0 millivolts

Secondary voltage = 30 volts

$$\alpha = \text{Tan}^{-1} \frac{0.03}{30}$$

$$\cong \frac{0.03}{30} = 0.001 \text{ Rad}$$

$$\equiv 0.001 \times 57.3 = .057 \text{ degrees}$$

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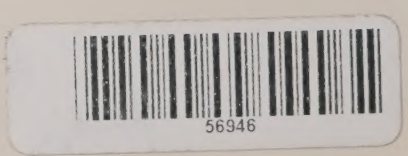
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